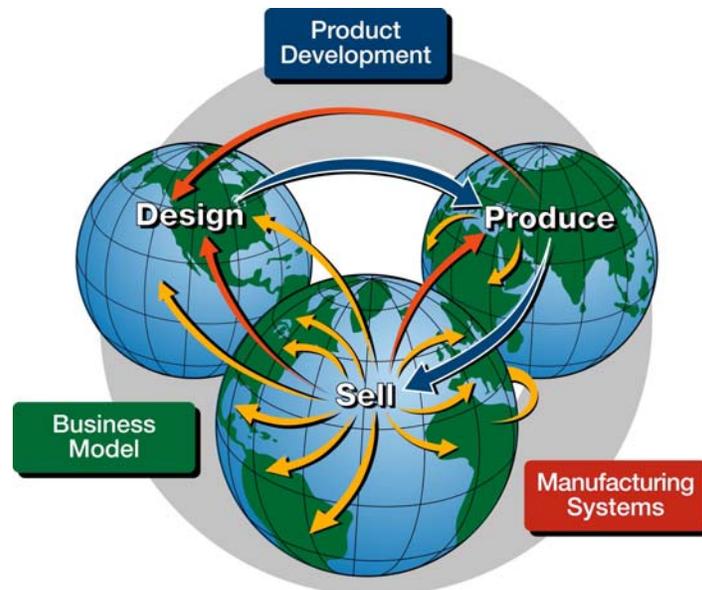


The Global Manufacturing Revolution

Product-Process-Business Integration
and Reconfigurable Systems

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The University of Michigan



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This textbook elaborates on how manufacturing enterprises can succeed in globalization. It shows that a revolution is needed in restructuring the three main units of manufacturing enterprises: product design, manufacturing, and business model. The book includes many numerical examples and home assignments.

Topics:

Globalization and Manufacturing Paradigms

Product Invention Strategy

Customized, Personalized, Reconfigurable Products

Mass Production Models

Analysis of Mass Customization

Traditional Manufacturing Systems

Economics of Manufacturing Systems

Reconfigurable Manufacturing Systems and System Configuration Analysis

Responsive Business Models for Global Manufacturing Enterprises

Enterprise Globalization Strategies

Where Are Manufacturing Enterprises Headed?

SELECTED DRAWINGS

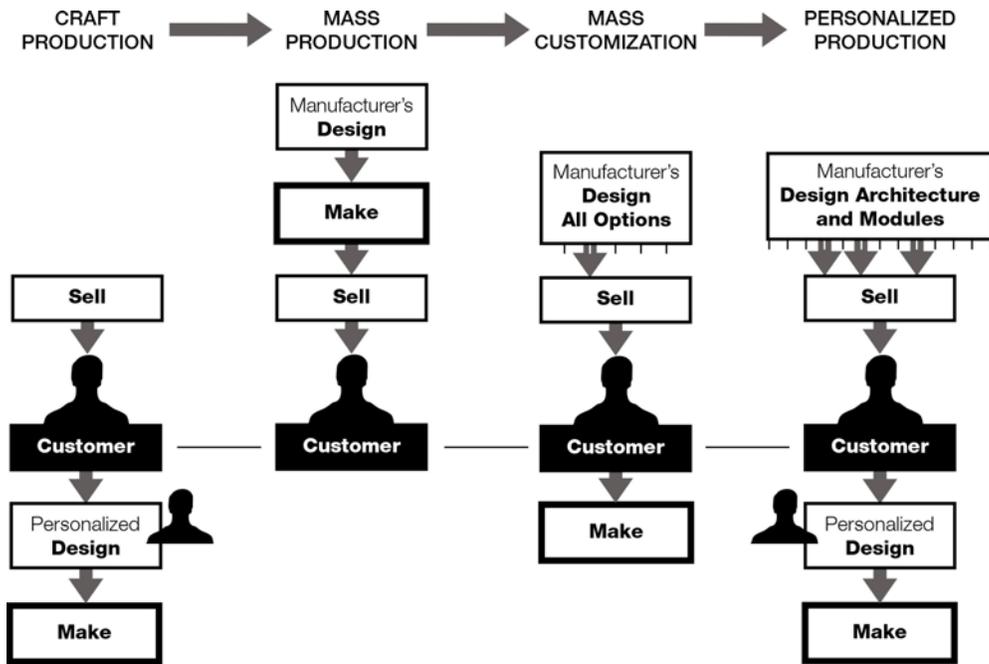


Figure 1.13. The customer role in the four paradigms
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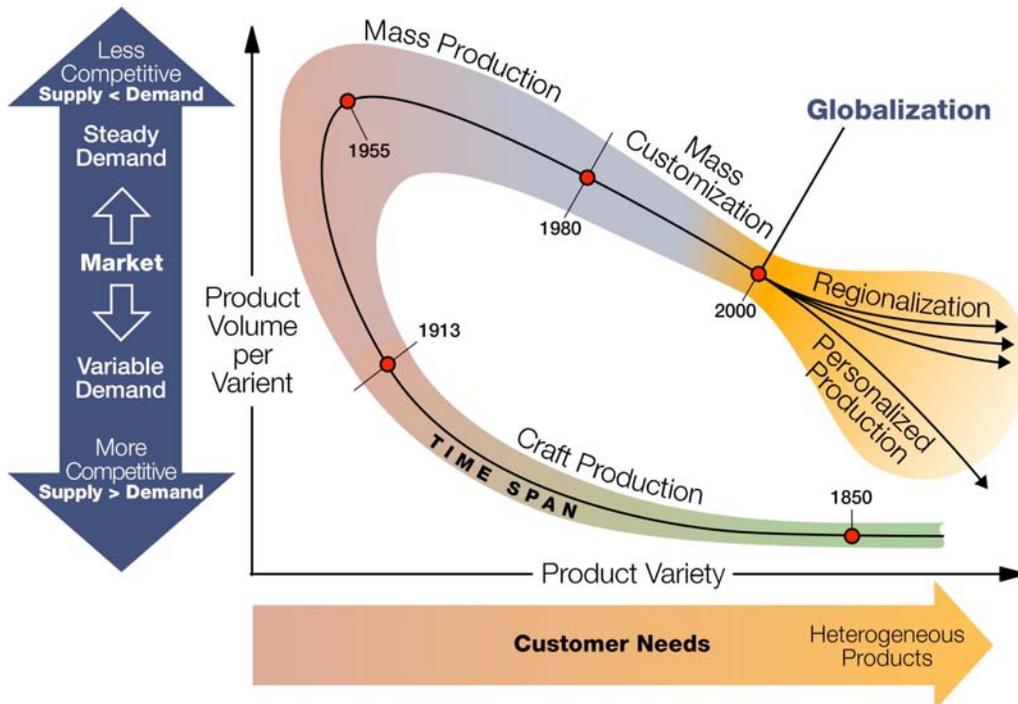


Figure 1.14. The drivers to new paradigms are market and society needs
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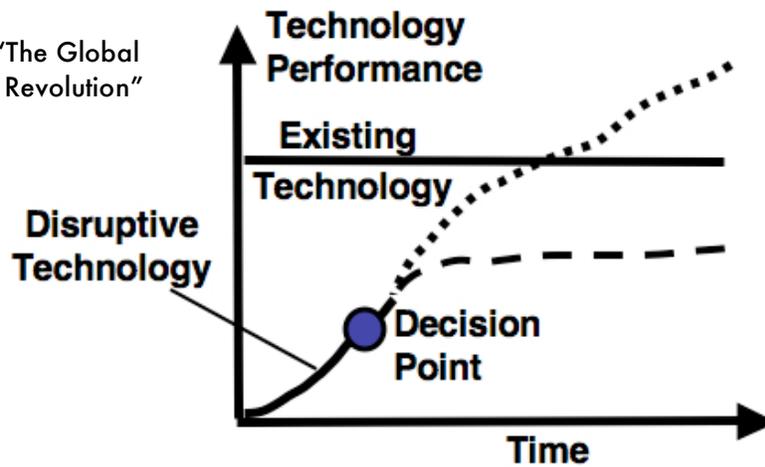


Figure 2.3. The dilemma of investing in a disruptive technology: Will its performance surpass that of the existing technology, or will its performance just improve a bit?

You can find the three main paradigms of manufacturing when you go to a restaurant. Fast food is basically mass-produced. In a regular restaurant, you order a particular dish from the menu – the fish comes with mashed potatoes and asparagus; this is the package. If you want to replace the asparagus with rice, it is impossible – you are experiencing “mass-customization.” But, if you go to a restaurant that has a large list of side-items (“modules”) that can be added in any combination to the main entrée, and you decide the combination of “modules” served personally to you, you have truly experienced personalization.



“No alcohol, extra sugar, please.” Rony, here is your personalized drink – just for you!

The interior of the car will be an open space. The customers will look at a computer monitor and design the interior of their car (see an example in Figure 3.4). The input will be some physical dimensions, such as the length of the hand and the driver’s effective reach. The computer will show the virtual interior space, and lead the customer through a step-by-step selection of desired modules from a given database (seats, computer monitors, cabinets, dog baskets, exercise equipment, etc.).



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Figure 3.4. A design of car interior

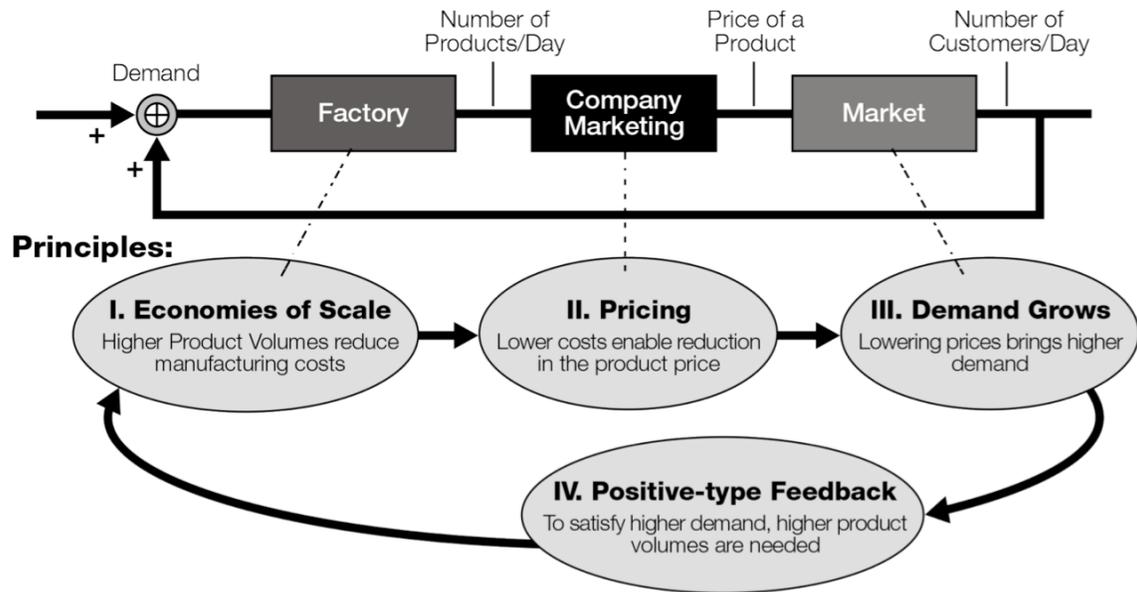
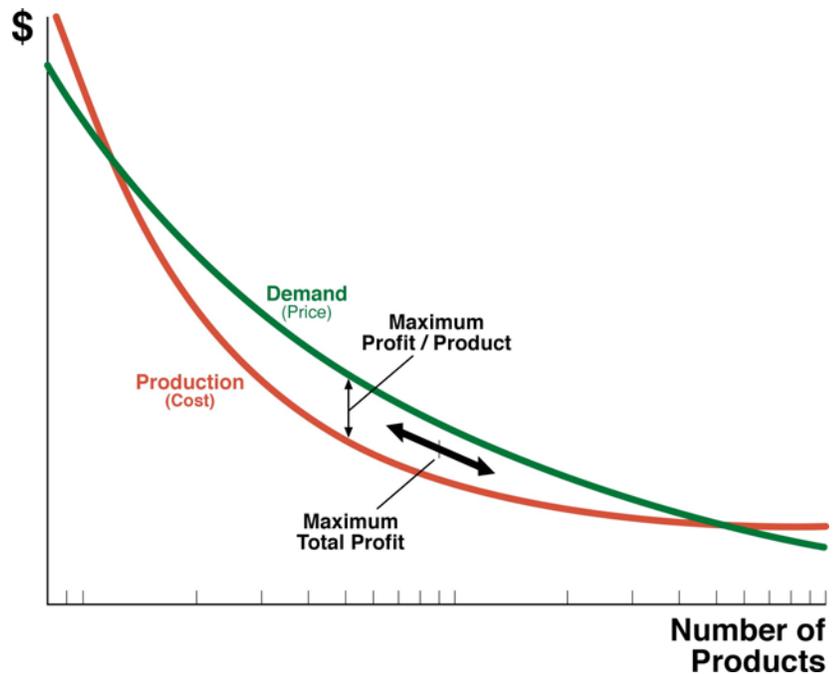


Figure 4.4. The mass production process is modeled as a closed feedback loop
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Figure 4.6.
 To be profitable, the manufacturer production curve must be below the demand curve



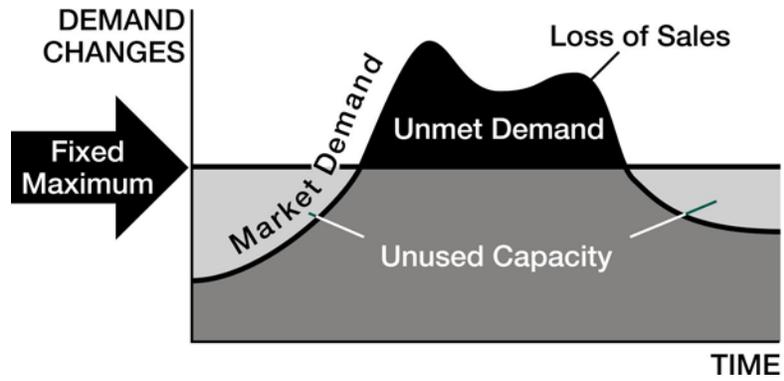
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Strategic Rules For Global Manufacturing Enterprises

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- 1. Global Strategy** The manufacturing enterprise must develop a global strategy that determines issues such as which products to develop, for which regions on the globe, where to locate factories, how to integrate global supply chains, and how to boost productivity with the same global resources. The enterprise should develop business strategies for emerging markets, such as Brazil, Russia, India, and China.
- 2. Integration of Product-System-Business** The global manufacturing enterprise must apply a systems-approach in which product design is integrated with the manufacturing system that will produce it, and with the business plan that sells it.
- 3. Rapid Responsiveness** The key to global success is faster responsiveness to customers' needs and market changes that is built into their business strategy as well as into their manufacturing system.
- 4. Reconfigurable Manufacturing Systems** The global manufacturing enterprise must possess reconfigurable manufacturing systems whose capacity can be easily changed to adapt to market demand, and its functionality can be cost-effectively adapted to introduce new products with short lead-times.
- 5. Innovative Products** The engine for a successful enterprise is a stream of innovative products introduced with short lead-times. Nurturing an enterprise culture of creativity and teaching creativity methodologies are imperative for continuous innovation.
- 6. Products Fit Regional Markets** The product design and its functions should fit the culture, regulations, climate and purchasing power of the target market customers. To reduce cost – design a common base (platform), and differentiate modules as necessary.
- 7. Personalized Products** An emerging market in industrialized countries is created around cost-effective personalized products – ideally, each product will be different and made exactly for an individual customer's needs and taste (a market of one).
- 8. Empowerment with Information** The enterprise must provide real-time continuous information to employees and empower them to make decisions; empowerment sustains a momentum for rapid innovation in both the product and the manufacturing system.
- 9. Critical Parts and Final Assembly** A cost-effective manufacturing strategy that also protects intellectual property is to build assembly plants in the target market country but keep production of critical parts at home.
- 10. Strategic Alliances** Combine the skills and resources of alliance partners to develop innovative products at the highest quality and lowest production costs.

Figure 6.7. A DML system is an excellent choice when it is operating at its designed throughput capacity, which cannot be easily changed. Losses can occur in unmet demand when a product is popular, as well as in unused capacity as its popularity wanes.



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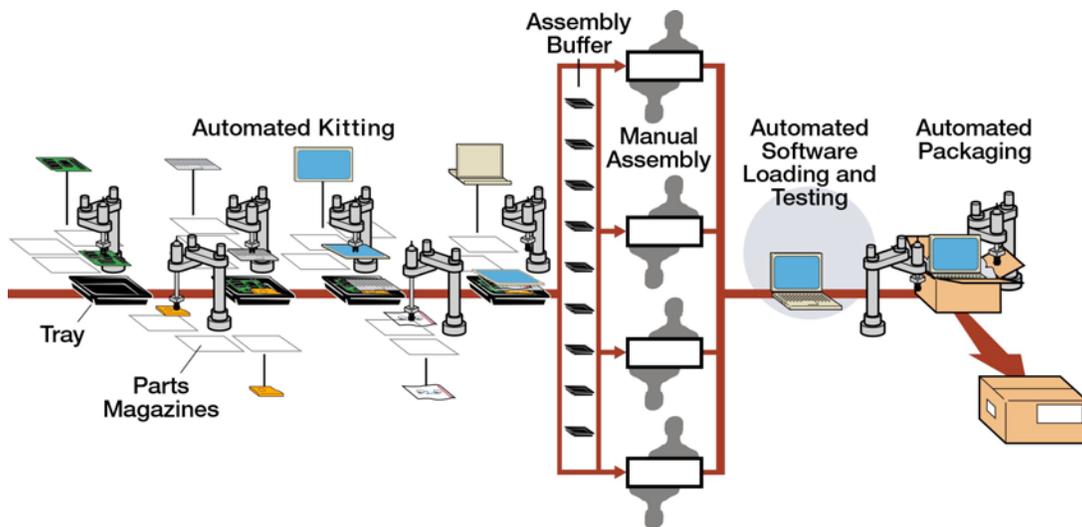


Figure 6.14. A typical flexible assembly system for personal computers
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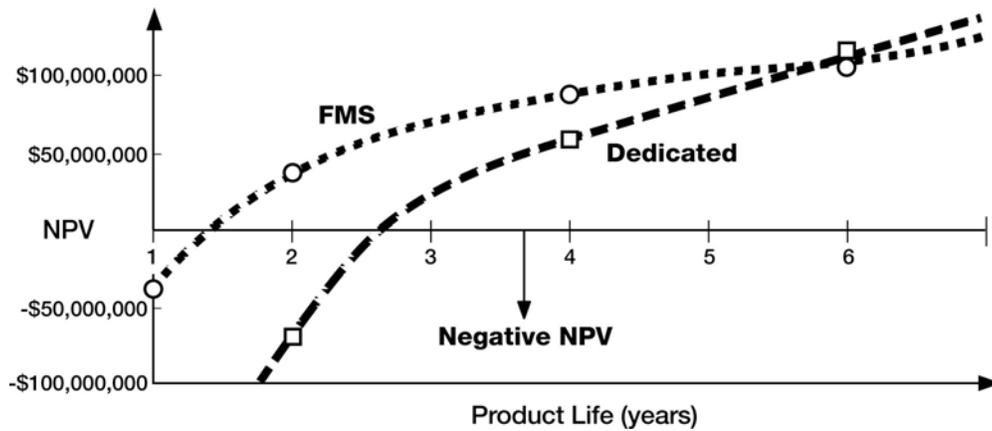


Figure 7.1. An economic comparison of two systems: Dedicated and FMS
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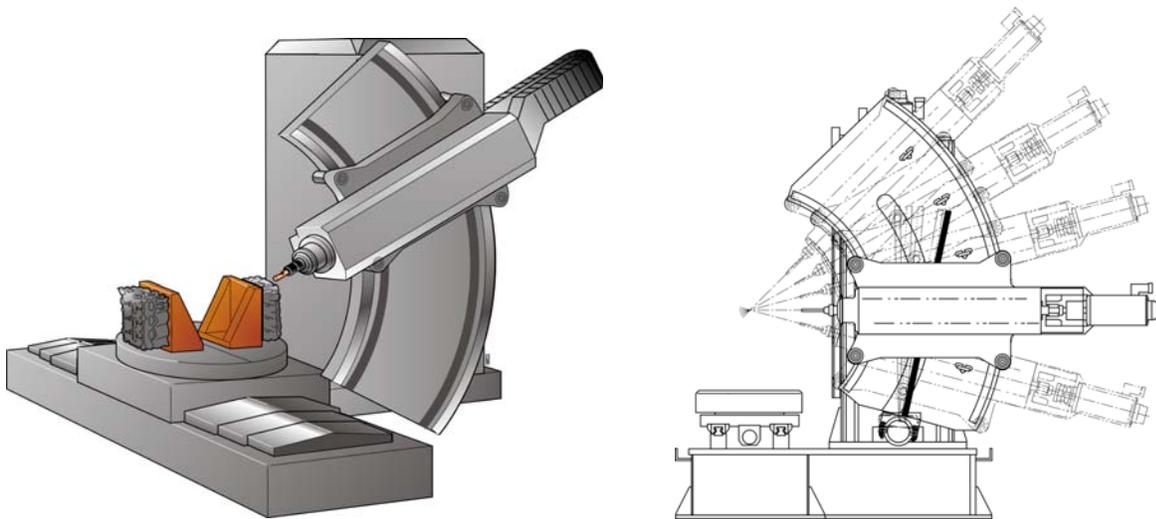


Figure 8.11. Arch-Type RMT – conceptual design; the inclined angle can be changed from -15° to 60°

Figure 9.1. Goals of manufacturing plants

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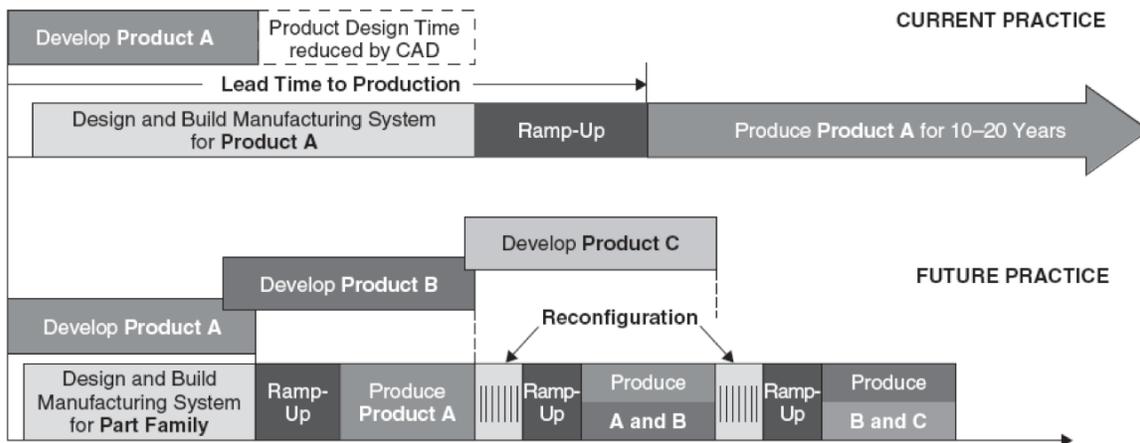
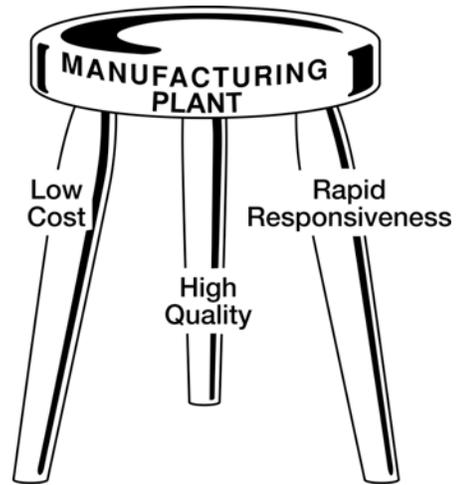
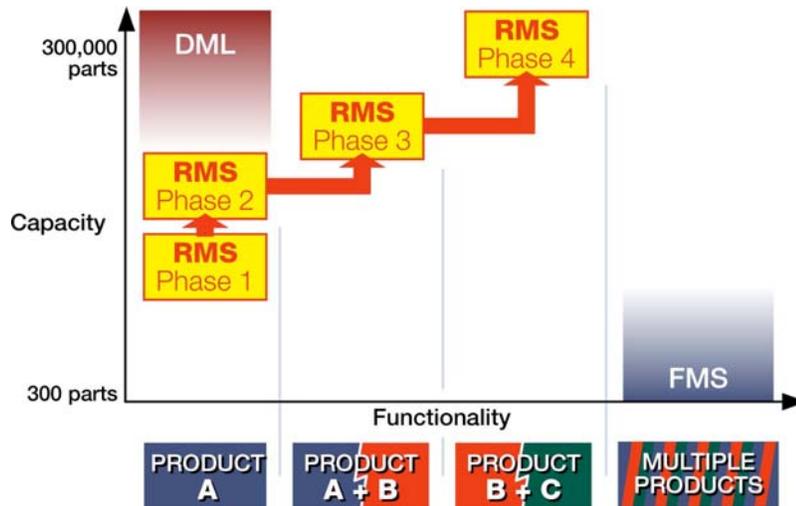


Figure 9.2. Product development time was reduced dramatically by the introduction of CAD systems. However, something equivalent has yet to be done with the manufacturing system (top) itself. Increasing the frequency of new product introductions requires shortening the manufacturing system lead-time, enabled through rapid reconfiguration.

Figure 9.4. Both DML and FMS are static systems; the RMS is a dynamic system that can change capacity and functionality in response to market changes



Design Principles of Reconfigurable Manufacturing Systems

1. The RMS provides **adjustable production resources** to respond to unpredictable market changes and system intrinsic occurrences:
 - RMS capacity can be rapidly scalable in small increments
 - RMS functionality can be rapidly adaptable to new products
 - RMS inbuilt adjustment capabilities enable rapid response to unexpected equipment failures

2. The RMS is designed around **a part or a product family**, with just enough customized flexibility needed to produce all members of that family

3. The **RMS core characteristics** should be embedded in the whole system as well as in its components (mechanical, communications and control)

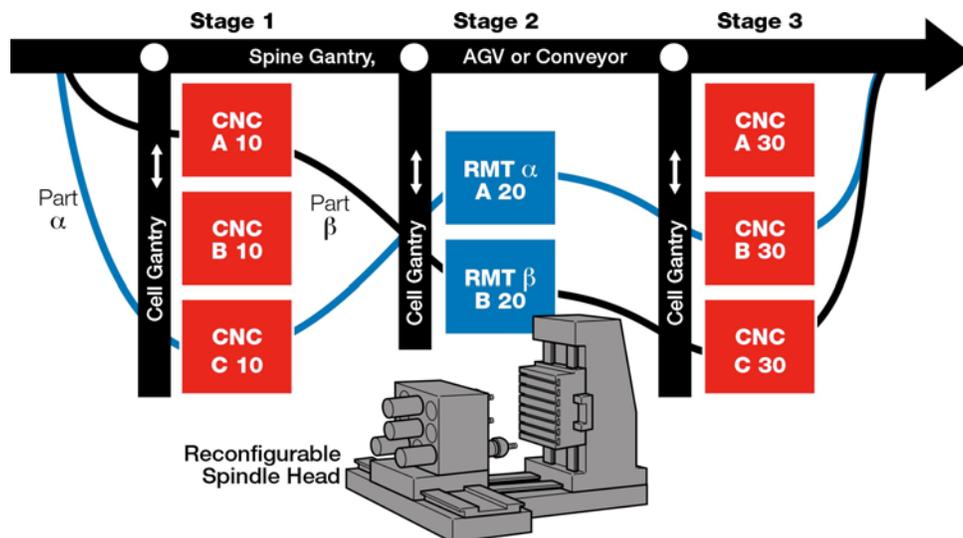


Figure 9.9. RMS with integrated reconfigurable machine tools (RMT)

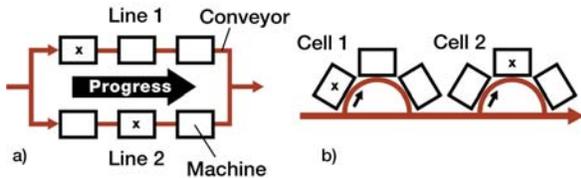


Figure 10.5. Parallel lines, or cells
(If the two marked machines fail, the system production stops)

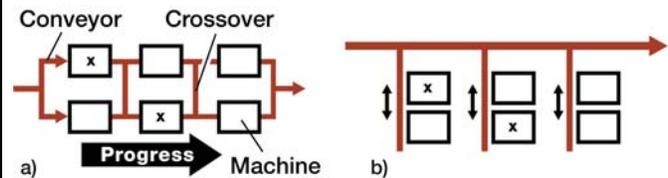


Figure 10.6. RMS configuration
(If the two marked machines fail, the system still has 50% production capacity)

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$$K = \sum_{m=1}^N \binom{N-1}{m-1} = 2^{N-1} \quad (10-3)$$

The number, K , of possible configurations with N machines arranged in exactly m stages is:

$$K = \left(\frac{(N-1)!}{(N-m)!(m-1)!} \right) \quad (10-4)$$

For example, for $N = 7$ machines arranged in up to 7 stages Eq. (10-3) yields $K = 64$ configurations, and if arranged in exactly 3 stages, Eq. (10-4) yields $K = 15$ RMS configurations. The mathematical results of these two equations for any N and m may be arranged in a triangular format, known as a Pascal triangle, shown in Figure 10.9.

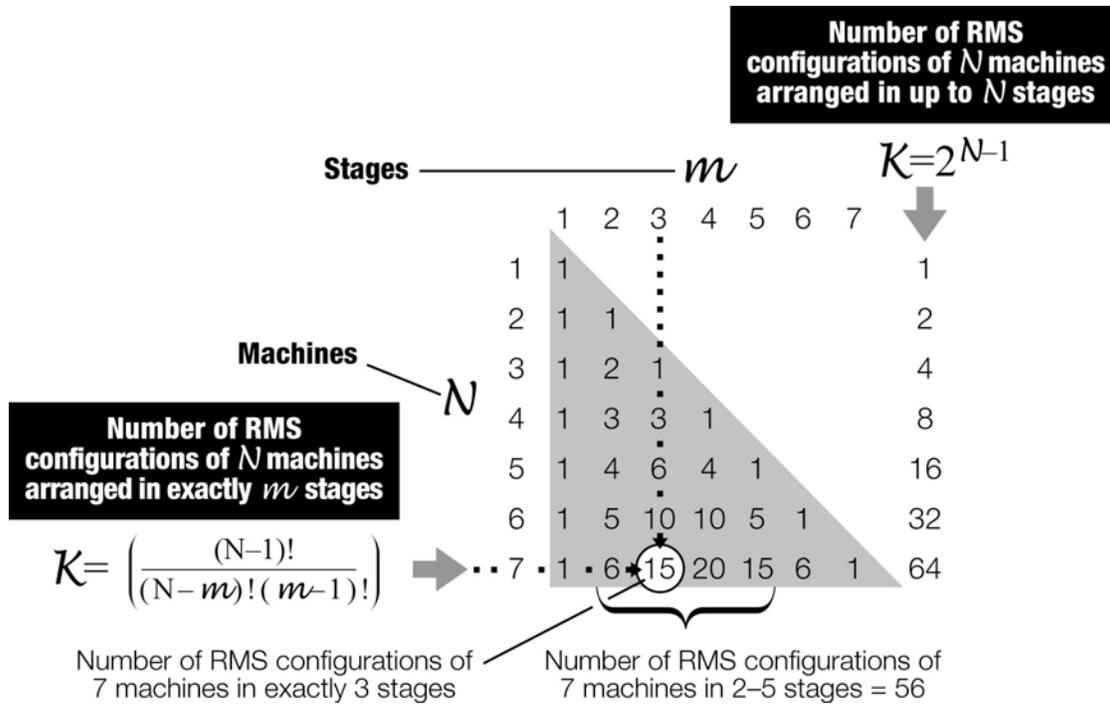


Figure 10.9. The Pascal Triangle is helpful in calculating the number of RMS configurations

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Markets Change

You Can't afford to be slow . . .

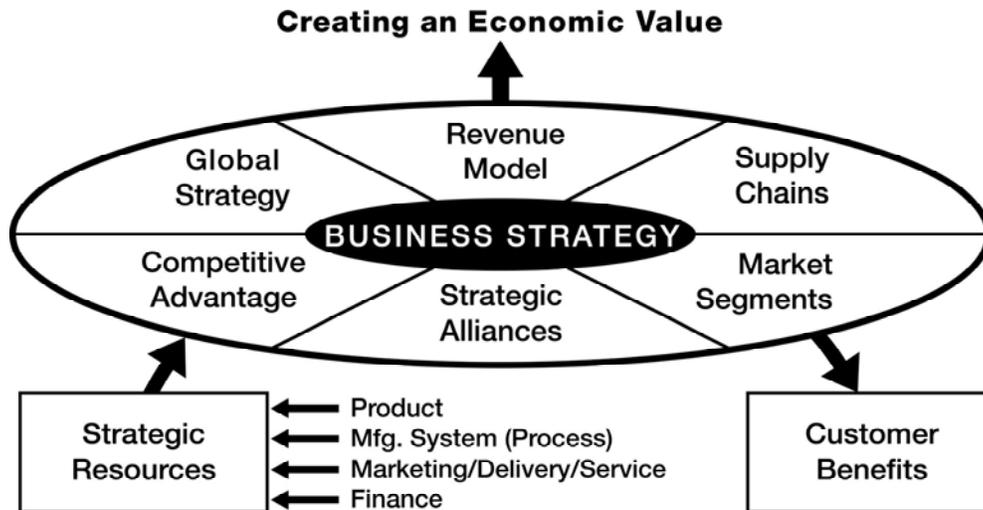
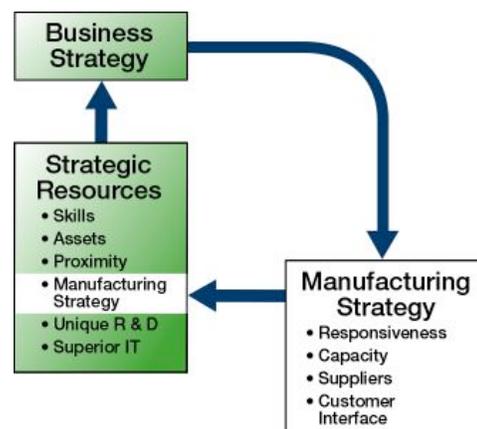


Figure 11.1. The business model flow-chart
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Comparison: Cost Leadership, Differentiation, and Product Personalization

| | Cost Leadership | Differentiation | Personalization |
|----------------------|-----------------------------------|---------------------------|--|
| Strategy Focus | Process Innovation | Product Innovations | Customer's involvement in product design |
| Manufacturing System | Dedicated; Mass-production plants | Flexible; High-Mix plants | Reconfigurable & Flexible; Buyer-to-plant link |
| Production Strategy | Products made to stock | Products made to order | Products designed and made to order |

Figure 11.2. The bond between the manufacturing strategy and the business strategy



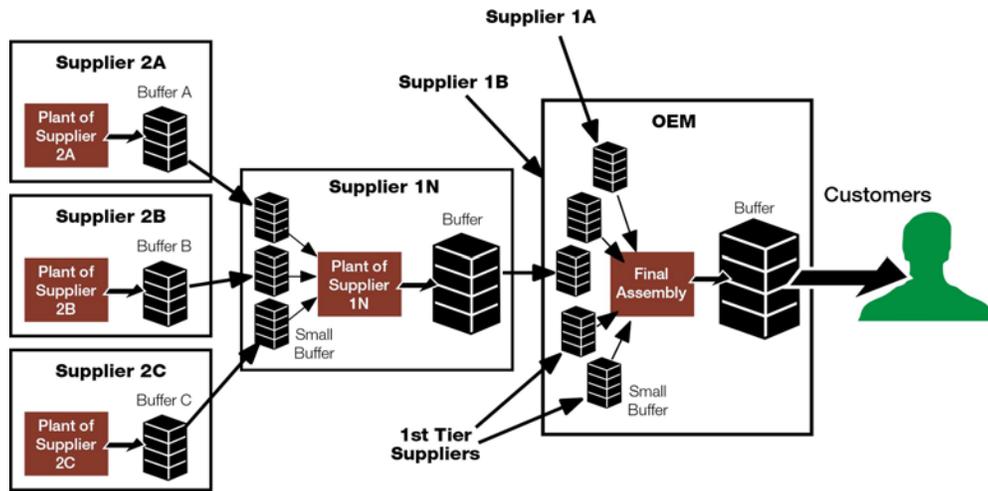


Figure 11.3. A basic supply chain

Figure 11.4. The total cost as function of the ordered quantity

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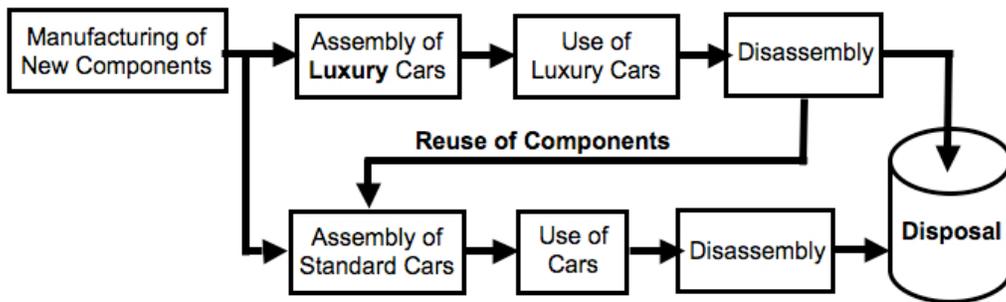
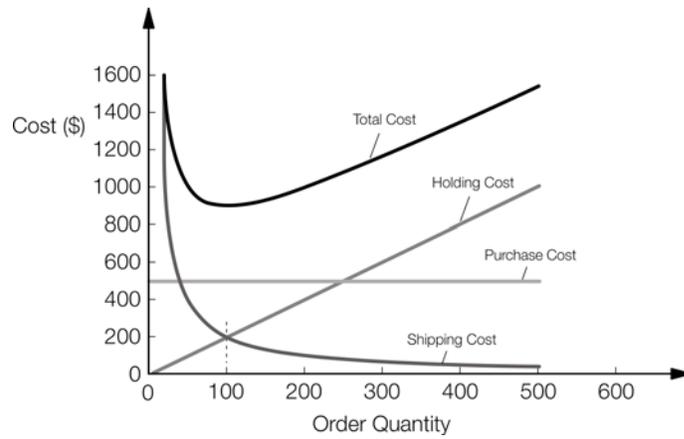


Figure 11.8. Reuse of old components in less expensive products reduces disposal

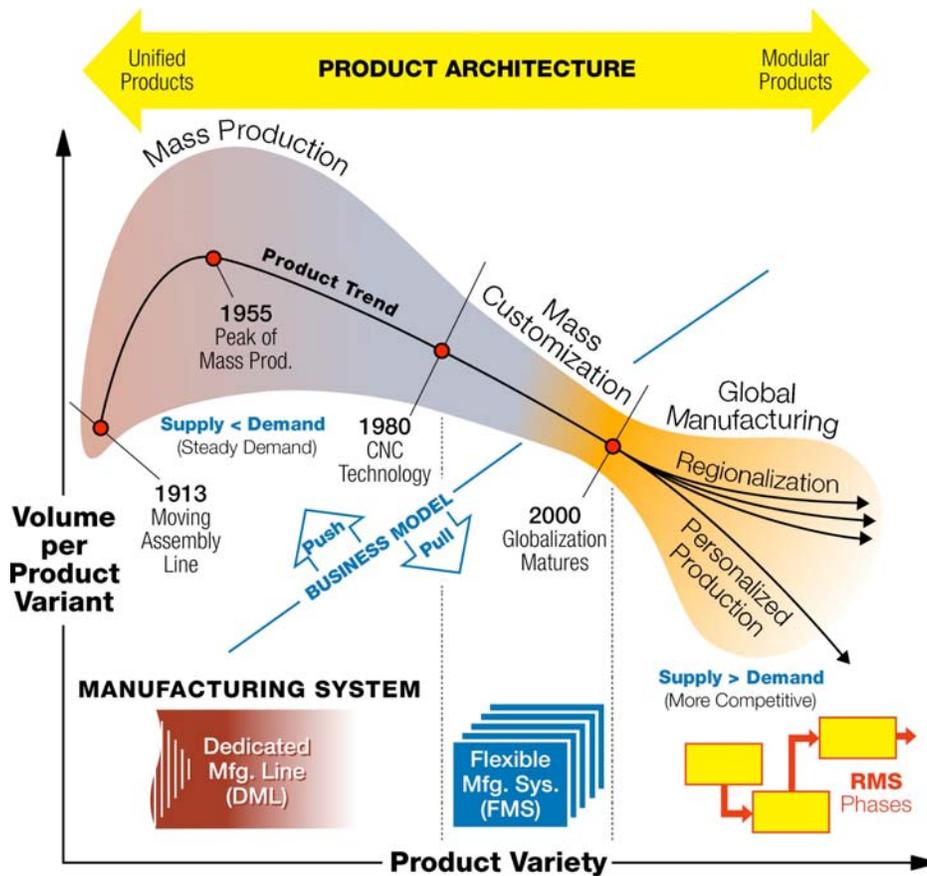


Figure 14.5. Paradigms and their product, process and business characteristics
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Yoram Koren is a member of the US National Academy of Engineering, and is internationally recognized for innovations to flexible automation & robotics, and for conceiving the reconfigurable manufacturing paradigm. According to Google Scholar, more than 8000 papers have cited professor Koren’s work in these areas.

Professor Koren is the founding director, in 1996, of the Engineering Research Center (ERC) for Reconfigurable Manufacturing Systems (RMS), sponsored by the National Science Foundation. During 11 years of NSF sponsorship, the Center —comprised of 20 professors, 10 investigators, 8 staff, hundreds of graduate students and 25 companies— received \$48 million in funding. Numerous ERC/RMS inventions that increase plant productivity and enhance product quality were implemented in US factories

Professor Koren holds 14 U.S. patents. He is the author of 270 papers and three award-winning books that have been translated into French, Japanese and Chinese. “*The Global Manufacturing Revolution*” is his newest, fourth book.