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Reinterpreting the Resource-Capability View of the Firm: A Case of the Development-Production Systems of the Japanese Auto Makers

by

Takahiro Fujimoto
The University of Tokyo

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Takahiro Fujimoto, Associate Professor,
Faculty of Economics, The University of Tokyo

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1. Introduction

The present paper has two main purposes: conceptual and empirical. Conceptually, the paper will propose a reinterpretation of so called "resource-based" or "capability" theories of the firm from an information system point of view, so that they can be effectively applied to detailed analyses of production and product development systems in a single business situation. Empirically, the paper will try to illustrate the capabilities of product development and production at the effective automobile manufacturers in Japan during the 1980s (mainly Toyota), explain how the capabilities contributed to their competitive advantages, and analyze how they evolved over time.

Resource-based or capability theories of the firm has attracted much attention among business academics and practitioners in recent years. They illustrated a business firm as a collection of firm-specific resources, organizational routines, capabilities and competencies, which may explain inter-firm differences in competitiveness, as well as inter-temporal dynamics (i.e. evolution) of business enterprise systems[1].

On the other hand, competitive strength of some of the Japanese auto makers, such as Toyota, became a hot issue during the 1980s, as the global market share of the Japanese cars continued to increase and the Japanese assemblers and parts makers started up their transplants in the US and Europe. Empirical researches on productivity, manufacturing quality and product development performance revealed competitive advantages of the Japanese auto makers over average Western makers in this period[2]. Practices and techniques of competitive Japanese auto makers, as well as philosophies behind them, were introduced to the Western readers[3]. By the end of the decade, the view that the source of their competitiveness was not so much certain individual techniques or technologies as the overall pattern of the total manufacturing-development system prevailed among the

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[1] For the concepts of resource, organizational routine, capability and competence, see, for example, Penrose (1959), Nelson and Winter (1982), Wernerfelt (1984), Itami (1984), Chandler (1990, 1992), Praharad and Hamel (1990), Grant (1991), Leonard-Barton (1992), Teece, Pisano and Shuen(1992), Kogut and Kulatilaka (1992), Iansiti and Clark (1993), and Teece, Rumelt, Dosi and Winter (1994). For evolutionary aspects of the firm and its strategies and technologies, see, also, Dosi (1982), Nonaka (1985), Kagono (1988), and Mintzberg (1989).

[2] See, for example, Harbour (1980), Abernathy, Clark and Kantrow (1981, 1983), Womack, Jones and Roos (1990), Fuss and Waverman (1990), Clark and Fujimoto (1991, 1992), and Cusumano and Takeishi (1991).

[3] For example, Ohno (1978), Nihon Noritsu Kyokai, ed. (1978), Shingo (1980), Monden (1983, 1993), Schonberger (1982), Toyota Motor Corporation (1987), Coriat (1991).

researchers and practitioners of this field[4]. Some parts of the system was in fact transferred to the Western countries in the 1980s and 1990s through the Japanese transplants, inter-firm coalition, and bench marking studies by the Western makers, which all contributed to the catch-up of some American and European auto makers during the same period[5].

Given the basic facts that inter-firm and inter-regional differences in the overall patterns of manufacturing and product development systems resulted in significant performance differences across the firms, and that the patterns of the competitive Japanese auto companies emerged during the post-war period, it seems natural to predict that the resource-capability theories of the firm can be effectively applied to the case of the Japanese auto makers. Thus, the present paper tries to examine applicability of the resource-capability approach to the production and development systems in a single international industry.

For the above purpose, however, the existing frameworks of the resource-capability approach needs some modification and reinterpretation. While most of the existing resource-capability literature, found in the field of strategic management, applied economics or business history, analyze the dynamics of the overall systems of multi-product firms, they are not designed for detailed competitive analyses of a production and product development systems at a single plant or project level, which researches in technology and operations management often focus on[6]. For a better match between the resource-capability approach and the detailed competitive analyses of manufacturing systems, this paper proposes a reinterpretation of such basic concepts as firms, products, resources, activities, competitive performance and capabilities consistently from the information's point of view by describing the product development and production processes and their outputs as assets, creation and transmission of value-carrying information that is ultimately embodied in the product.

In section 2, key concepts of the resource-capability framework will be reinterpreted from the information point of view[7]. The capability in product development and manufacturing will be classified into three levels: current, improvement, and evolutionary. In

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[4] See Womack Jones and Roos (1990), Clark and Fujimoto (1991), and so on.

[5] For the activities of the Japanese transplants, see, for example, Shimada (1988), Suzuki (1991), Kenny and Florida (1992), Abo, ed., (1994), Fujimoto, Nishiguchi and Sei (1994).

[6] Such recent literature as Chandler (1990), Prahalad and Hamel (1990) and Teece, Rumelt, Dosi and Winter (1994) mainly analyze the multi-product or multi-industry situations.

[7] This framework was gradually developed from Fujimoto (1983, 1989).

section 3, core elements of the development-production systems of effective Japanese auto makers (e.g., Toyota-stele production system) will be illustrated and reinterpreted in terms of information. Section 4 will turn to the issue of the long-term evolution of the system, and present a some cases of system emergence. Section 5 will examine some historical evidences by applying the concepts of historical imperatives and firm-specific evolutionary capabilities.

For simplicity of discussion, the present paper will focus only on the single product situation, as opposed to multi-product or multi-business setting. Second, while performance of business firms, in a broad sense, includes contribution to and satisfaction of employees, stockholders, communities and so on, the present paper will focus only on market competitiveness and customer satisfaction. Third, although competitiveness of a product may be also influenced by such marketing factors as sales force, advertisement and packaging, it will be assumed that the product itself and its price (product cost) are the only factor affecting competitiveness.

2. Development-Production Capability : An Information Approach

2.1 Information Defined

As mentioned earlier, the present paper tries to match the resource-capability theories of the firm with a case of technology and operations management by reinterpreting such basic concepts as firm, product, consumption, resource, activity, competition, and capability in terms of information assets, creation and transmission. It should be noted that, in the present paper, "information" is defined very broadly as patterns of material or energy which potentially represent some other events or objects[8]. The definition is basically that in general system theories, and is broader than that in Shannon-Wiener type theories of information, management of information literature, information processing theories of organizations, and

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[8] For further details of the definition, see Fujimoto (1989, p. 70).

microeconomics. That is, in the present definition, computer data, human knowledge, symbols, as well as shapes of press dies are all regarded as a certain type of information.

The present paper emphasizes the concept of information for the following reasons: Values to the customers, embodied in product and its price, are jointly created and delivered by product development and production, so the two subsystems should be analyzed as a total system; Product development is essentially cumulative creation of information assets for commercial production; Commercial production is essentially repeated transmission of product design information from the process to the product; Therefore, information is a common denominator that can be consistently used for the analyses of resource and capability in product development and production.

The following part of this section will briefly reinterpret key concepts of the resource-capability framework based on the above assumptions.

2.2 Firms, Products and Consumption

Business firms can be seen as open systems of material, energy and information stocks and flows. By focusing on the information aspect, material and energy can be regarded as media on which value-carrying information is stored, transferred or transformed.

Products are primary outputs of manufacturing firms to the market. In the information view, the essential part of what manufacturing firms deliver to the customer is a bundle of information or messages that each product carries, rather than the product itself as a physical object . The information that the product delivers to the customers has two aspects: *structure* (i.e. form) and *function*. Structural information is stored in the product, while functional information is transmitted from the product to the customers as they interact with a certain user environment. Manufacturing firms absorb information from outside, create potentially value-carrying information thorough product development and production activities, ultimately embody it in the physical product, and deliver it to the customers[9].

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[9] Although sales and marketing is another indispensable function for delivery of the value-carrying information, it was omitted in this paper for simplicity.

Consumption is also regarded as information processing or information creation by the customers[10]. In other words, what customers ultimately consume is not the physical object, but the bundles of structural and functional information that the product transmits to the customers. They receive the information from the product, interpret it, compare it with their expectations, and generate satisfaction (or "value" in the marketing sense) for themselves. Thus, customer satisfaction is jointly created by the firms providing the product-embodied information and the consumers attaching meanings to it.

2.3 Resource as Information Asset

The bundle of information that the products eventually embody is gradually developed through a network of what Penrose (1959) calls *productive resources* within manufacturing firms. In the information view, each productive resource (more precisely, developmental-productive resource) can be regarded as an information asset that consists of a combination of the value-carrying information and a medium (figure 1.a).

The information component of the developmental-productive resource represents certain functional or structural aspects of a product, and is deployed in the development-production system. As product development and production processes go on, the information becomes refined from product concepts to basic or functional product designs, finalized as detailed (structural) product designs, translated and deployed in production processes, and is eventually transmitted to the products. We may call such information *product deign information* or *value-carrying information*, as it is designed to represent a certain aspect of the final product, and is intended to carry certain values to the target customers. Thus, the information component of the resource tends to be product-specific and firm-specific.

The product design information, an intangible pattern or form, does not exist without *media*. Physical materials, human brains, blank papers and various computer memory devices are all media that can potentially embody the product design information within the firm. At each stage of the production-manufacturing process, the appropriate media that can

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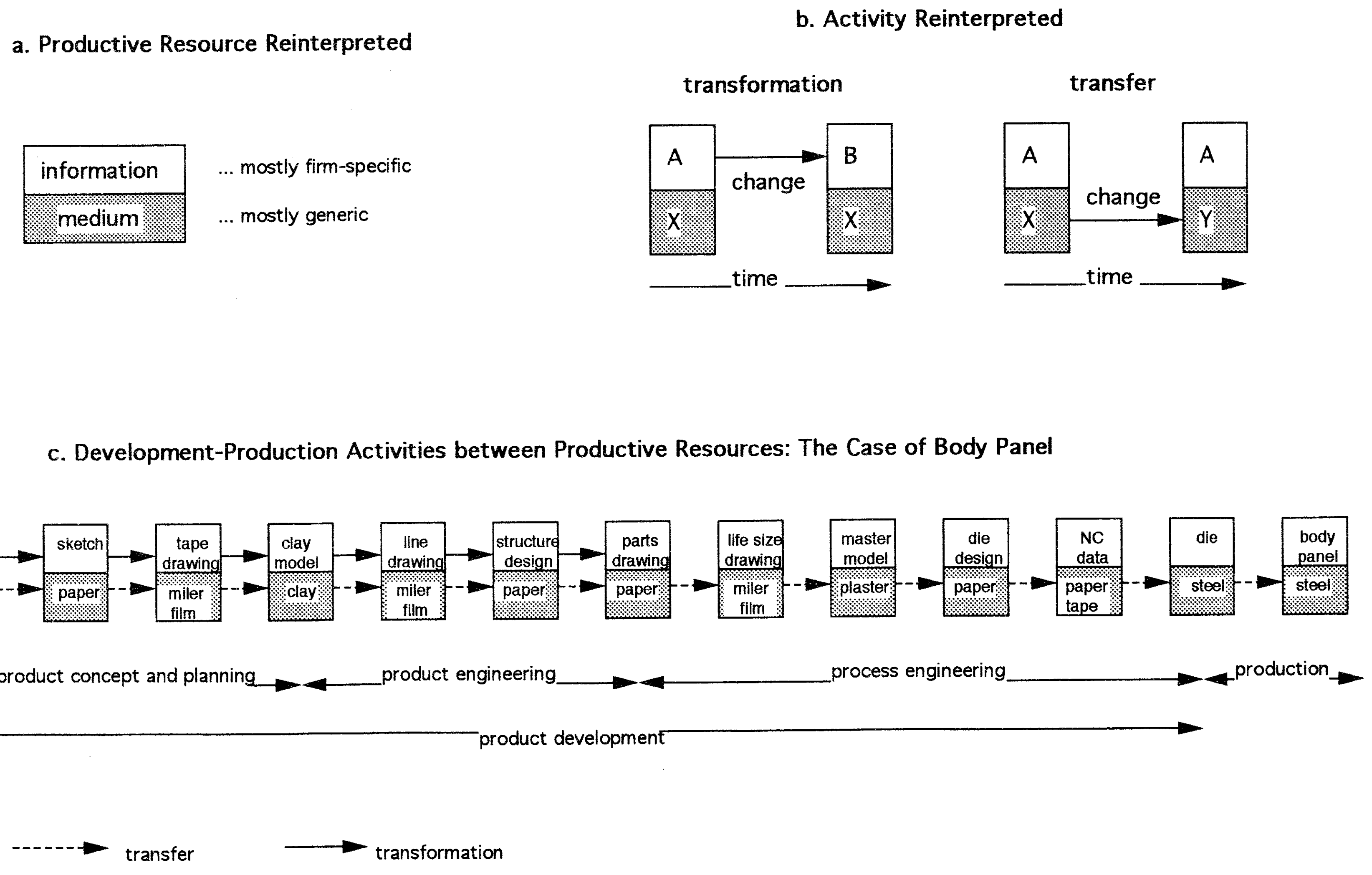
[10] The information processing approach is a prevalent model in the field of consumer behaviors. See, for example, a standard text book by Robertson, Zielinski and Ward (1984). Some economists, such as Lancaster (1966), also analyze a product as a bundle of intangible service. For further details of this discussion, see Fujimoto (1989, p. 97).

Figure 1 Information View of Resource and Activity



a. Productive Resource Reinterpreted

b. Activity Reinterpreted

c. Development-Production Activities between Productive Resources: The Case of Body Panel receive, store, modify and transmit the information are deliberately chosen. When a firm purchases the "blank" media without product design information (e.g., untrained workers, raw materials, general purpose equipment), we can regard them as undifferentiated production inputs in the sense of classical economics.

The media mix of a firm's productive resources may change over time. For example, bureaucratization and Taylorism can be regarded as media switches from human-embodied resources (e.g., craft skills) to paper-embodied ones (e.g., manuals); Hard automation is the switch from human-embodied to capital-embodied resources in the production process; Programmable automation is the shift to the computer-embodied resources.

Thus, the concept of productive resources (in Penrose's term) can be reinterpreted as certain information assets, each of which consists of a pair of value-carrying information and a medium. A firm's manufacturing and product development system consists of interrelated productive resources. While using rather undifferentiated media purchased from outside (i.e., production inputs), the productive resources become firm-specific, to the extent that the content of product design information and the patterns of interactions between the productive resources is different across the firms. The product itself is an example of a productive resource, and so are dies, jigs, tools, standard operating procedures, product-specific skills of the workers, numerical control data for machine tools, prototypes, engineering drawings, computer-aided-design files, clay models, design sketches, technical papers, market research reports, product concept proposals, and so on.

2.4 Activity as Information Processing

Activities of product development and production (or what Penrose calls productive service) can be regarded as information flows or processing between productive resources that cause changes in their information content and/or media (figure 1.b). It is a combination of *transfer* (the same information changes media) and *transformation* (information content changes on the same medium)[11]. An example of automobile body design and stamping is

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[11] Another type of activity is *transportation*, in which the same resource (information + medium) simply changes locations.

illustrated in figure 1.c, in which the product design information for the body panel is gradually created, transformed, and transferred though a series of activities in product development and production.

Product development activities can be described as a cumulative process of information creation and transmission, which gradually develops information assets necessary for commercial production (figure 2.a). In the case of the automobiles, there are four major stages of product development: product concept generation, product planning (i.e., functional and basic designs), product engineering (i.e., detailed and structural designs), and process engineering (i.e., production preparation). At the end of process engineering, elements of production processes are deployed for commercial production at the shop floor.

A set o activities for developing a product, often called a project, consist of many *problem solving cycles* connected to one another[12]. Each of the cycles includes generation of alternative designs, as well as evaluation and selection of them in light of objectives of product development: customer satisfaction. Product development activities are also essentially a *simulation* of future production and consumption processes[13]. That is, performance of product development is affected by accuracy of the simulation.

Production activity can also be regarded as *transfers* of the product design information from the production process to the product (figure 2.b). At each station of the process, a fraction of the product information, stored in the workers, tools, equipment, manuals and so on, is transferred to material or work in process, which "absorbs" the information step by step and is transformed eventually to a product. In the field of production and operations management, the sequence of transformation in which the materials and work in process receive the information is often called " process flow," while the transfer of the information from a given station is usually called "operation."

Thus, product development and production activities jointly develop productive resources, exchange information between them, and deliver the product-embodied information bundle to the target customers[14].

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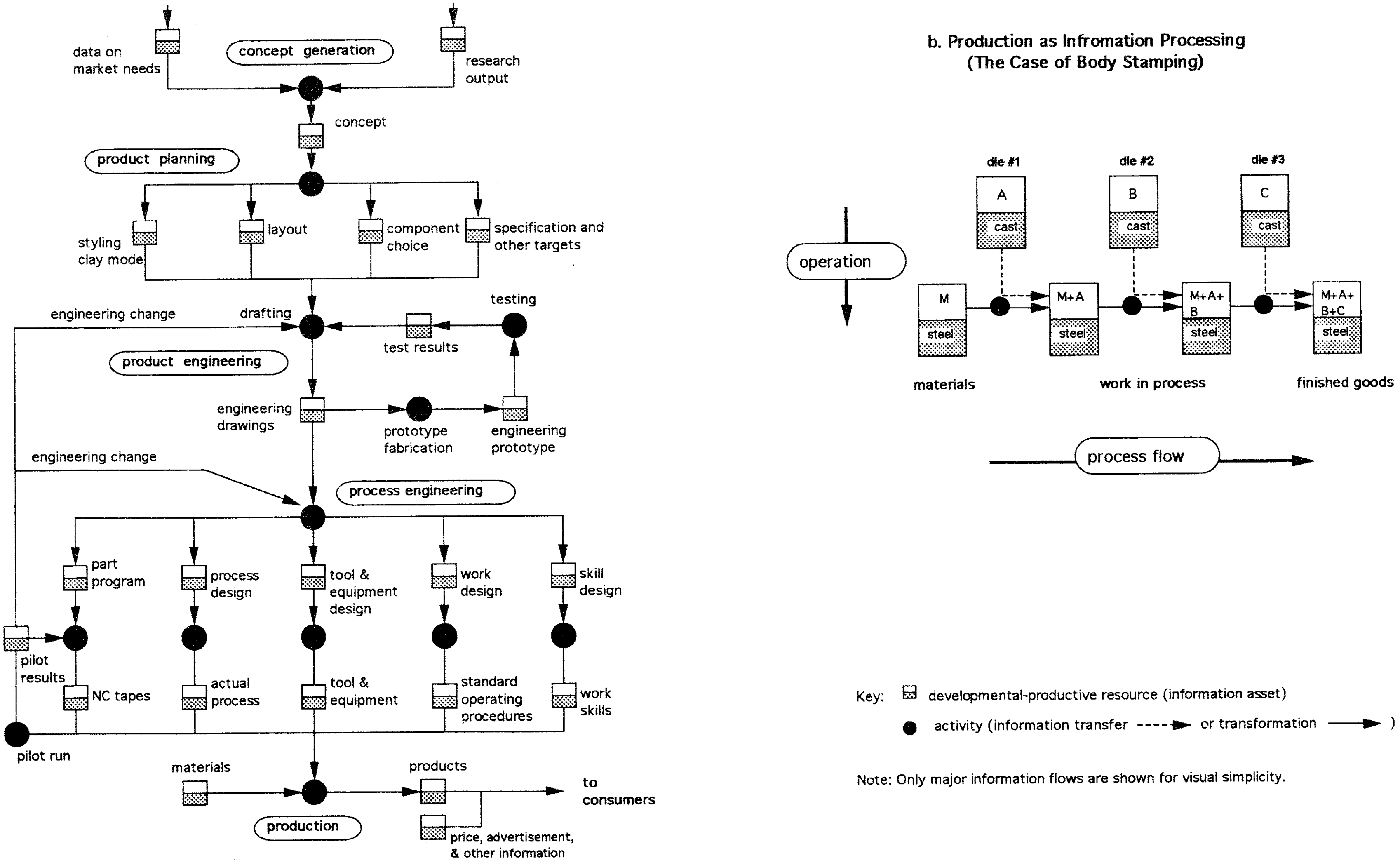
[12] Clark and Fujimoto (1991, Chapter 2). A standard model of problem solving, such as Simon (1945, 1969) and March and Simon (1958), is applied here.

[13] Clark and Fujimoto (1991, Chapter 2).

[14] Marketing function is omitted for simplicity of the analysis.

Figure 2 Product Development and Production Activities as Information Processing



a. Product Development as Infromation Processing

b. Production as Infromation Processing
(The Case of Body Stamping)

Note: Only major information flows are shown for visual simplicity.

2.5 Competitive Performance and Its Dimensions

In the present framework, *competitiveness* of a product can be defined as the influence of the product-embodied information bundle to attract and satisfy potential and existing customers. As such, product competitiveness is a joint result of manufacturer's ability of providing distinctive product (i.e., information bundle) and customer's ability of discerning and interpreting the information.

A firm's system of resources and activities in product development and production can contribute to its product competitiveness through at least three dimensions: product quality, productivity, and throughput time. Product quality is related to fitness of the information content or accuracy of information transmission, while productivity and throughput time measures efficiency of information transmission between productive resources.

Productivity and Throughput Time: By viewing production activities as transmission of value-carrying information from the production processes to materials or work-in-process, one can reinterpret productivity and throughput time as *efficiency* of information transmission and information reception respectively.

First, *factor productivity* in manufacturing (at a given process step for a given product) can be regarded as efficiency of information transmission from a factor in production processes, such as worker and equipment to work in process or materials. It affects product competitiveness through unit product cost, given the unit factor price. For example, labor productivity at a certain work station, measured by work hours per unit, can be seen as efficiency in transfer of value-carrying information from the worker to the work-in-process. For this particular transmission, the following simple identity applies (figure 3)[15]:

$$\underset{\text{(factor productivity)}}{\frac{\text{work hours}}{\text{unit}}} = \underset{\text{(density of transmission)}}{\frac{\text{work hours}}{\text{value-adding time}}} \times \underset{\text{(speed of transmission)}}{\frac{\text{value-adding time}}{\text{unit}}}$$

where, work hours = value-adding time + non-value-adding time

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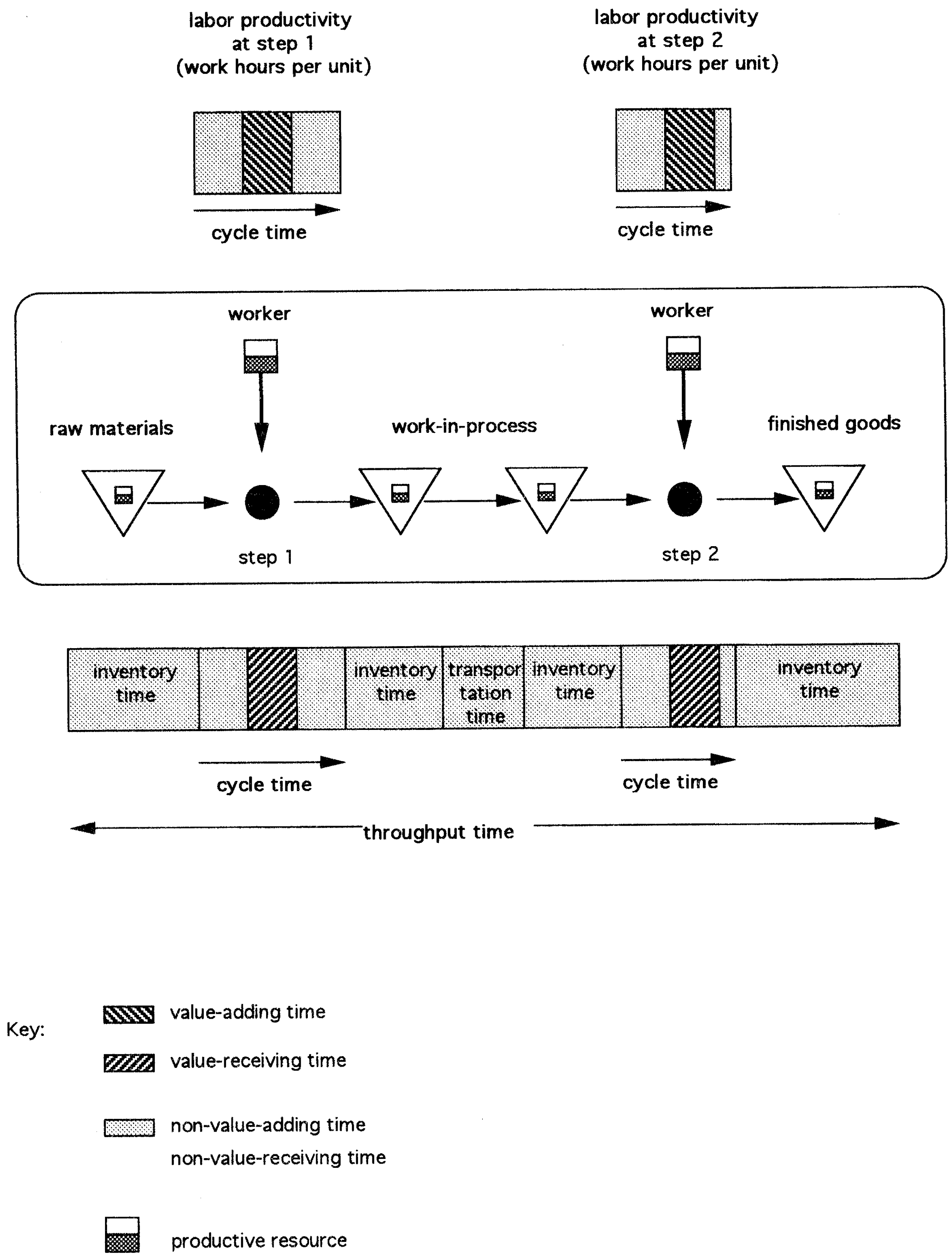
[15] For simplicity, a linear production process of identical products and single-person operation at each process step is assumed in figure 3.

Figure 3 Factor Productivity and Throughput Time: A Conceptual Case



= average cycle time x number of units produced

This identity implies that, given the product design, a high level of labor productivity at this process can be achieved by either of the two methods: increasing *density* of information transmission by reducing such non-value-adding time as waiting, walking and set-up, or increasing *speed* of the information transmission itself by performing each individual value-adding task more quickly, or introducing new production technologies for faster processing. The same logic applies to the case of machine productivity: the former measure includes reducing machine break down time, set up time and air-cutting time, while the latter includes increasing the cutting and feeding speed with improved tools, materials and machines.

Second, *throughput time* is elapsed time from reception of a given material to shipping of the product. It affects delivery time to the customers in the case of production to order; in the case of production to stock, shorter throughput time may improve accuracy of demand forecast and thus reduce both finished goods inventory and stock outs. While factor productivity in volume production means efficiency of information transmission on the senders' side (i.e., workers and equipment in a given operation), throughput time refers to efficiency and speed of information absorption on the side of the receivers (i.e., materials and work-in-process in a given process flow). As in the case of factor productivity, total throughput time corresponding to a given process flow is divided into value-receiving time (= value adding time), during which transformation of the work-in-process goes on, and non-value-receiving time (figure 3). When the process flow consists of a sequence of production steps, one can reduce throughput time by reducing non-value-receiving time such as inventory time (including materials, work-in-process, and finished goods), transportation time between the steps, waiting time of the work-in-process within each process step, and so on[16]. Alternatively, throughput time can be shortened by speeding up the value-receiving process itself at each step (including parallel operations of value-adding tasks). As the company reduces throughput time, the process flow becomes more efficient in making the

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[16] Integrating multiple process steps into one can be included in this category.

materials absorb information from the production steps and transforming them into final products.

Quality as Accuracy of Information Transmission: The concept of product quality, in the present framework, is related to *fitness* of information content or *accuracy* of information processing along a chain of productive resources that links customer needs, product concepts, product designs, process designs, process, and products (i.e., the chain of quality; see figure 4)[17]. *Total product quality* ("fitness for use" in the definition of Juran) measures how the information content embodied in the actual product matches the customer needs and expectations. It can be decomposed, along this chain, into design quality and conformance quality.

Conformance quality (also called manufacturing quality) measures how well the information embodied in the actual products corresponds to that in the product design. Once the complete set of detailed product design information is developed at the product engineering stage, it is transferred to process design, to the actual processes deployed on the shop floor, and eventually to the final product. However, product design information is subject to deterioration through this chain of quality. To the extent that the transmission errors accumulate between product designs and actual products, the information that the products ultimately carry deviates from what the company intended at the product design stage, and conformance quality goes down.

Design quality, on the other hand, means fitness of the product design with the target customer expectations, or intended product quality at the design stage. It measures how well the customer expectations are translated into product concepts and then into detailed product designs. As the chain of quality indicates, a high level of total product quality is achieved only when both design quality and conformance quality are high. Even when design quality is very high, its value does not reach the customers if conformance quality is low; When conformance quality is high, customers are not satisfied when the product design does not fit the customer expectations in the first place.

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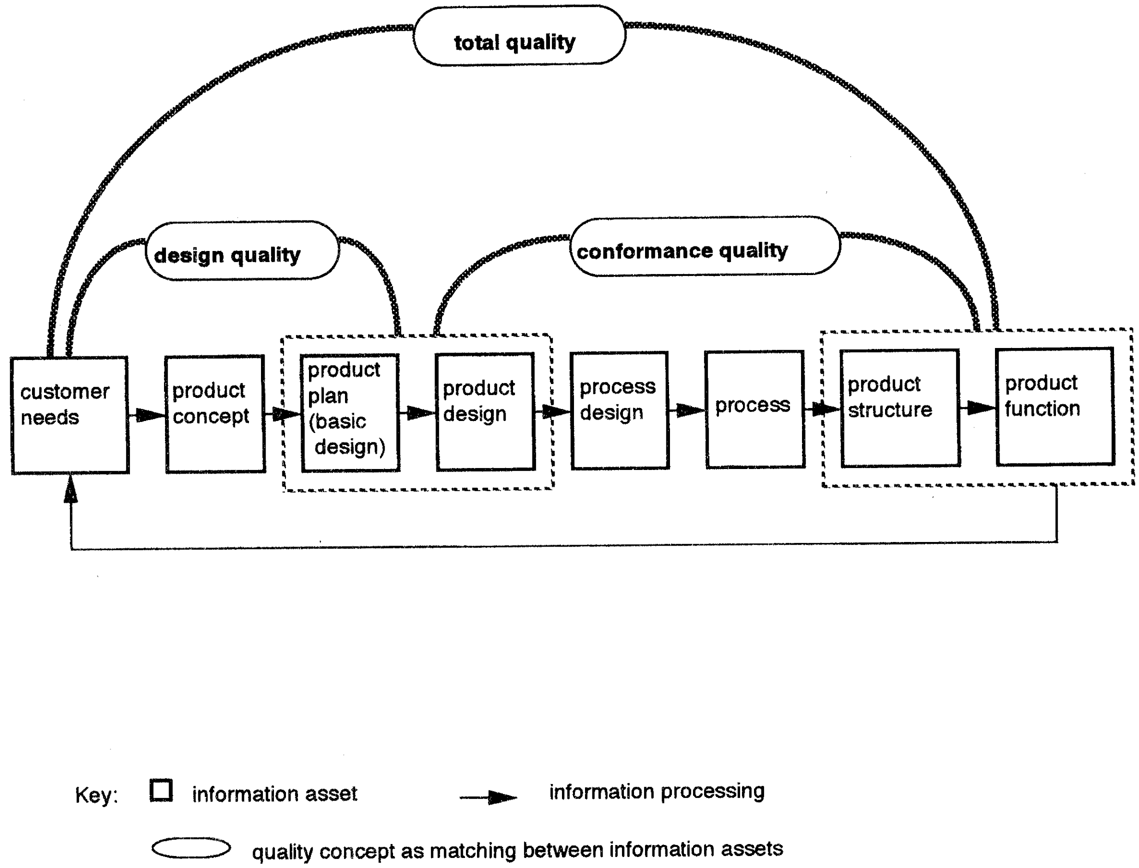
[17] For the concepts of product quality, see, also, Juran, Gryna and Bingham, eds. (1975), Garvin (1984), Groocock (1986), and so on.

Figure 4 Quality Chain and Quaity as Accuracy of Information Processing



Source: Adopted from Fujimoto, Takahiro. "Organizations for Effective Product Development." 1989.

Flexibility as Information Redundancy: Although the concept of flexibility in the development-production system has many aspects, let us focus for now on the case of flexibility in cost against product variety[18]. It has functional and structural aspects.

Functionally, flexibility absorbs the cost impact of product variety. In modern mass production, It costs manufacturing firms significantly to develop and maintain such productive resources as machines, workers and blueprints. When single-model mass-production is prevalent (e.g., Ford Model T), firms pursue simple economy of scale, in which each productive resource transmits the same information to as many products with identical design as possible, multiplying the information and spreading the cost over them. When the market is diversified and firms produce different products, however, some of the productive resources need flexibility in order to enjoy "economy of scope." The cost impact of product variety is absorbed through two steps: First, *parts flexibility,* with modular component designs shared by multiple products, reduce the variety of parts designs while maintaining the product variety; Second, *process flexibility* further reduce the variety of production processes for making a given set of products and components (figure 5.a). The two types of flexibility jointly reduce the cost impact of the product variety.

Structurally, flexibility against variety means redundancy of information stocks in a given productive resource. When a unit of productive resource is flexible, it contains both general-purpose information stock and product-specific information stock (figure 5.b). For example, flexible stamping process consists of general-purpose press machines and product-specific (or product-family-specific) dies; flexible machining system has general-purpose NC (numerical control) machines and product-specific NC programs; flexible assembly workers master both general and product-specific skills; flexible (modular) product design consists of common parts and product-specific parts. In this way, the cost for general-purpose elements is spread over different products. At the same time, each productive resource carries redundant information in that all of its information is not activated when a particular product is made. Similar logic holds in the case of flexibility against changes in production volume and product designs.

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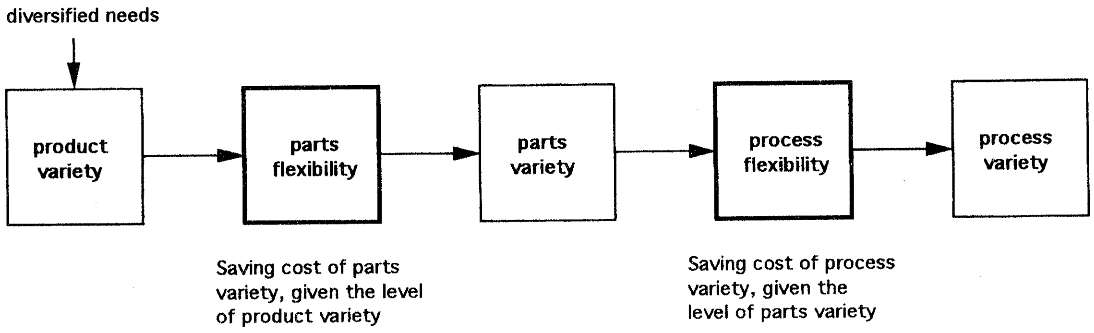
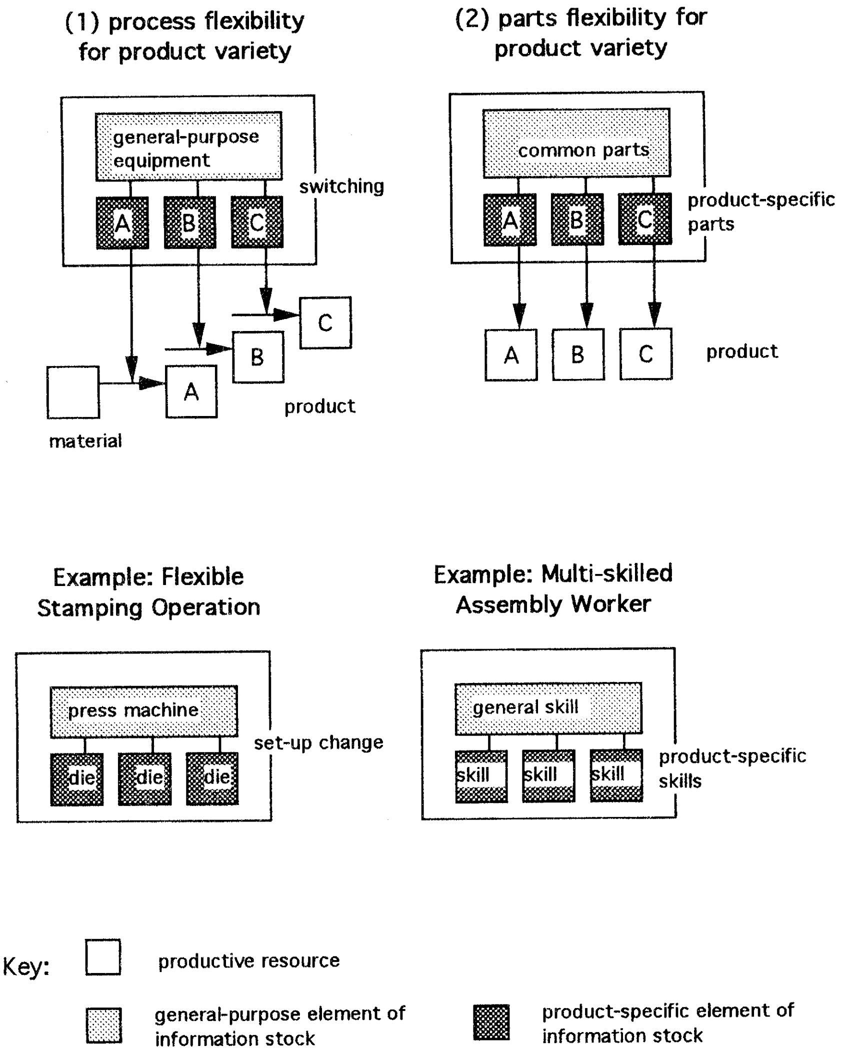
[18] For the concept of flexibility in general in manufacturing, see, for example, Browne, J., Dubois, D., Rathmill, K., Sethi, S.P., and Stecke, K.E. (1984).

Figure 5 Flexibility as Redundancy of Information Stock

a Function of Flexibility to Variety



b Structure of Flexibility to Variety



Having reinterpreted the main dimensions of firms' competitive performance from information's point of view, let us now explore the concept of production-development capability, a main focus of this paper.

2.6 Three Levels of Development-Production Capabilities

We can now redefine capability in production and product development as follows: *Development-production capability* of a firm refers to certain firm-specific patterns of productive resources and activities (i.e., information stocks and their creation and transmission) that results in competitive advantages over its rivals. Assuming that both competitive performance and capabilities change over time, we have to distinguish at least three levels of firms' capability: (1) *static capability*, which affects the level of competitive performance, (2) *improvement capability*, which affect the pace of performance improvements, and (3) *evolutionary capability*, which is related to accumulation of the above capabilities themselves (table 1)[19]. The latter two can be regarded as the first-order and second-order dynamic capabilities respectively.

Static Capability: capability of consistently achieving a high level of competitive performance. As discussed earlier, several aspects of development-production capability affect the levels of product competitiveness: design quality, conformance quality, factor productivity, throughput time, and flexibility. As such, current capability is related to accuracy, efficiency, and speed of information creation and transmission between productive resources (i.e., information assets), as well as information content and redundancy of the resources themselves.

Improvement Capability: This refers to the ability of the development-production system for consistently and quickly achieving improvement in competitive performance such as quality and productivity. As this is essentially capability of repetitive problem solving and learning, it consists of the following sub-capabilities[20]:

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[19] Related concepts include static versus dynamic routines (Nelson and Winter, 1982), as well as dynamic capability (Teece, Pisano and Shuen, 1992).

[20] A standard linear model of problem solving is used here for simplicity (e.g., Simon, 1945, 1969; March and Simon, 1958). Problem solving activities in real situations may be less structured, less streamlined and less continuous. See, for example March and Olsen (1976) and March (1988). See, also, von Hippel and Tyre (1993).

Table 1 Three Levels of Development-Production Capability

	basic nature	influence on:	components
static capability	static & routine	level of competitive performance	productivity = efficiency of information transmission throughput time = efficiency of information reception quality = accuracy of information transmission flexibility = redundancy of information stock
improvement capability	dynamic & routine	change in competitive performance	problem finding problem solving retention of solutions
evolutionary capability	dynamic & non-routine	change in capability	pre-trial capability: ex-ante rationality entrepreneurial visions post-trial capability: ex-post rationality retention and institutionalization

Problem Finding: Ability of the system to reveal and visualize problems, diffuse problem information to problem solvers, keep consciousness to the problems, willingness of organizational members to accept higher performance goals, and so on.

Problem Solving: consistency between knowledge, skills, responsibility and authority for solving problems; levels and diffusions of tools for problem solving; knowledge sharing on alternative action plans and their effects, and so on.

Retention of Solutions: Ability of quickly and accurately formalize and routinize new solutions in standard operating procedures; stability of organizational members who internalize the solutions, and so on.

Evolutionary Capability: This refers to organizational ability of acquiring the static and improvement capabilities (i.e., capability of capability building). While improvement capability is routine in that it facilitates repetitive problem solving in a regular situation, evolutionary capability is non-routine, as acquisition of new capabilities is rather irregular and rare[21].

Evolutionary capability (i.e., the firm-specific ability of capability building) plays only a partial role in the overall evolutionary process of development-production systems, though. When a company changes its static or improvement capabilities to a new system, the firm-specific evolutionary capability may contribute to this "system emergence" process, but other factors such as environmental imperatives and pure lucks may also have significant influences on the change. After all, the evolutionary process of system emergence is a complex interaction between the firms and their environments.

Capability building can be regarded, in a broad sense, as a process of organizational learning and problem solving, as in the case of improvement capability. The problem is how to increase the firm's long-term competitiveness, and the solutions are a new set of development-production capabilities that the firm acquires. Unlike the case of improvement capability, though, the problem solving process here is much less streamlined, and the firms

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[21] For evolutionary theories of firms and technologies, see, for example, Abernathy (1978), Abernathy and Utterback (1978), Nelson and Winter (1982), Dosi (1982), Abernathy, Clark and Kantrow (1983), and Clark (1985). Such evolutionary theories tend to distinguish radical from incremental innovations (or "normal" from "extraordinary" technological changes) and make predictions on timing and frequency of each type of changes.

have much less control on the entire problem solving cycles. The problems and solutions are often disjointed. The regular sequence from problems to solutions to retention may not exist, as trials of solutions precede problem recognition in many cases[22]. Solutions to certain non-competitive problems may subsequently and inadvertently become solution for competitive problems. Thus, the standard model of problem solving cycles does not seem to be relevant to the case of evolutionary capability. This is one of the reasons why this paper analyzes improvement capability and evolutionary capability separately. Based on the above argument, let us further examine the process of system emergence.

2.7 System Emergence and Evolutionary Capability

Logic of System Emergence: Generally speaking, a new system of production and development gradually emerges as a result of a complex interactions of firms and environments, in which firm-specific evolutionary capability may play only a partial role. Thus, we have to analyze evolutionary capability of the firms in the broader context of the system emergence in general.

There are at least several alternative logic of explaining emergence of a new pattern of systems or capabilities (figure 6)[23].

- *Random trials:* This logic assumes that it is a matter of pure chance for an organization to choose a particular trial. A lucky one gets a better system, while an unlucky one gets a poor one.
- *Rational calculation:* An organization deliberately choose a new course of action that satisfies or maximizes its objective function by examining a feasible set of alternatives based on its understandings of environmental constraints and limits of capabilities[24]. In other words, this is the case of rational problem solving.
- *Environmental constraints:* An organization detects certain constraints imposed by objective or perceived environments, and voluntarily prohibit certain set of actions. The constraints may be objective (e.g. laws and regulations), or it may be a self restraints based on its perception of the environments.

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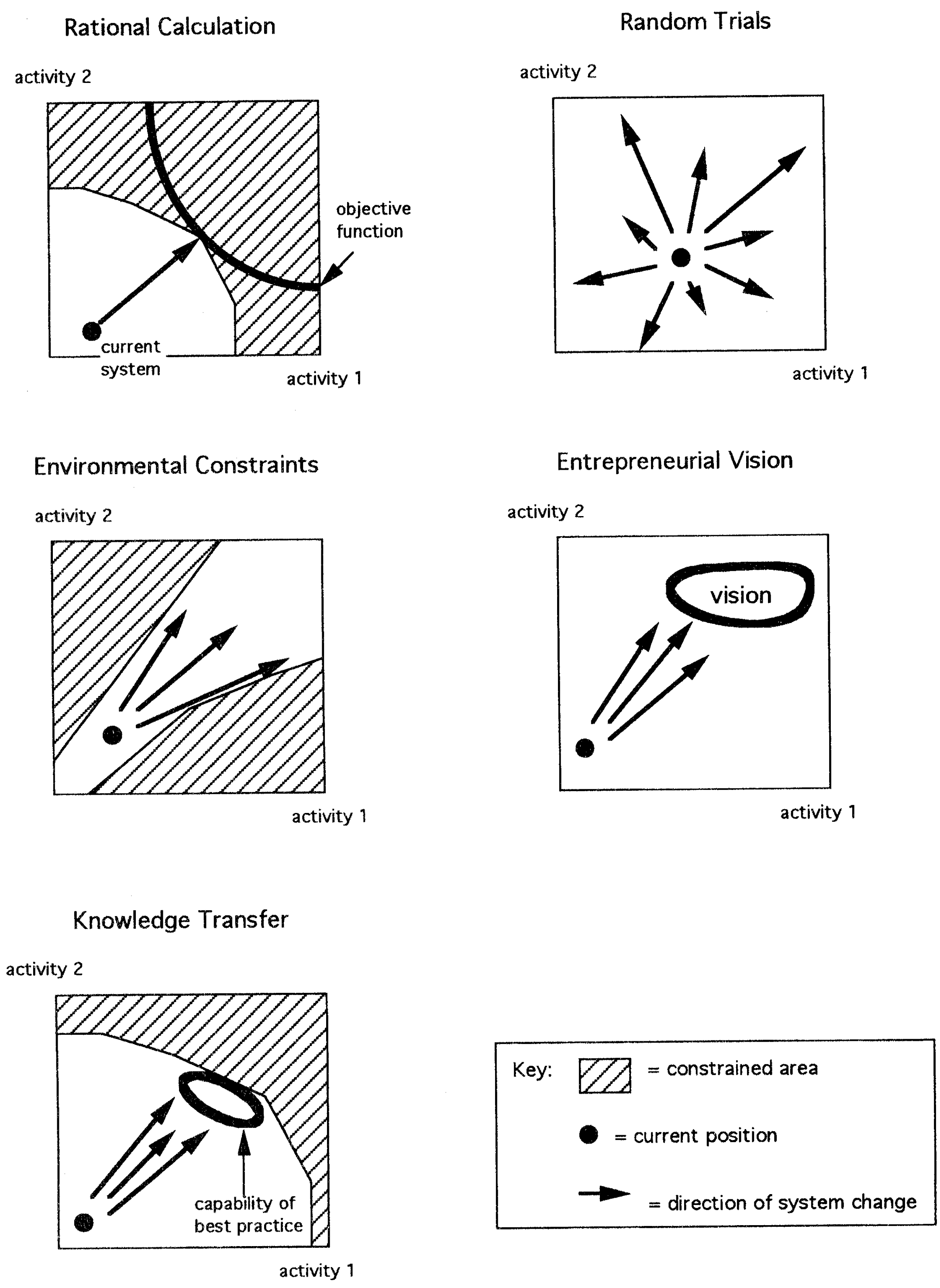
[22] See, also, the "garbage can" model in March and Olsen (1976) and March (1988).

[23] See, also, Fujimoto (1994a, 1994b).

[24] The neoclassical decisions further assume that the economic actors are equally capable and face the identical environment.

Figure 6 Some Generic Hypotheses of System Emergence


Rational Calculation

Random Trials

Environmental Constraints

Entrepreneurial Vision

Knowledge Transfer

Source: Adopted from Fujimoto, Takahiro. "The Origin and Evolution of the 'Black Box Parts' Practice in the Japanese Auto Industry." Tokyo University Faculty of Economics Discussion Paper 94-F-1, 1994.

- *Entrepreneurial vision*: A desirable set of activities is directly chosen by entrepreneurs of the organizations based on their visions, philosophies or intuitions without much analysis of their capabilities and constraints.
- *Knowledge transfer:* A certain pattern is transferred from another organization to the one in question. The transfer may happen within the industry (competitor, supplier, customer, etc.) or across the industries. Also, the transfer may be a *pull* type, where the adopter-imitator of the system takes an initiative, or it may be a *push* type, where the driving force of the transfer exists on the side of the source organizations.

A combination of different logic would be normally needed for explaining a particular system emergence. In any case, it should be noted that neither rational problem solving alone nor firm-specific dynamic capability seem to fully explain the evolutionary process of new system emergence.

Evolutionary Capability versus Historical Imperatives: Suppose that we have observed universally prevalent, region-specific, and firm-specific patterns of a certain development-production capability at the same time: a situation that researchers of a single international industry often encounter. How can we explain the evolution of such a pattern by the above logic of system emergence?

(1) *Universally prevalent* patterns of practice may emerge when rational problem solvers share identical objectives and constraints worldwide (a neoclassical situation), when the universally best practice has transferred to everyone, when severe selection environments allow only a particular pattern to survive, etc.

(2) *Region-specific* patterns of capabilities may emerge when the firms face region-specific environmental constraints or objectives, when knowledge transfers occur only within each region, etc.

(3) *Firm-specific* patterns may emerge when each company is allowed to take "random walk" in changing its systems, when each company faces different environmental constraints, when each company is lead by different entrepreneurial visions, when firms have different levels of problem solving capabilities, when knowledge transfers between firms are limited, etc.

Thus, although pure chances and historical imperatives often play important roles in the system emergence and capability building process, a company may still be able to build certain development-production capabilities faster and more effectively than the competitors by exercising certain evolutionary capabilities.

For example, certain historical imperatives may explain why the Japanese makers in general acquired certain region-specific capabilities, but it does not explain why certain Japanese makers have had better capabilities than other Japanese. To the extent that firm-specific patterns of performance and capability are observed, differences in each firm's evolutionary capability may matter.

It is also important to distinguish the following two types of evolutionary capabilities.

(1) *Pre-trial capability:* A firm's ability of finding and making trials or experiments for new capability acquisition earlier and more effectively than competitors. This category may include ability of rational calculations for identifying potentially effective trials (ex-ante rationality); entrepreneurial visions for intuitively finding effective trials.

(2) *Post-trial capability:* It often happens that trials for new capability are made inadvertently, and they turn out to be effective in competition. In this case, a firm can still create firm-specific advantages trough post-trial capabilities, including ability of grasping potential competitive consequences of the trials (ex-post rationality), and ability of routinizing and retaining the trials.

Thus, even when the competing companies do not differ in pre-trial capabilities or the level of ex-ante rationality, a firm may still be able to outperform the others by possessing better ex-post capabilities than the others.

Having illustrated and reinterpreted the resource-capability view from the information and evolutionary point of view, let us now apply the framework to the case of the relatively effective Japanese auto makers in the 1980s.

3 Development-Production Capability of Effective Japanese Makers

With the information approach to the resource-capability framework, this section will describe and analyze the development-production capability of effective auto makers of the 1980s, mainly Toyota's. Some "stylized" facts of such companies are listed up first, and they are interpreted from the information capability's point of view (Note that the main purpose of the paper is not to present new facts by rigorous methods, but to link generally accepted facts and the reinterpreted resource-capability theory).

3.1 Basic Facts in Production

Performance: The studies conducted in the 1980s repeatedly indicated that the average performance of the Japanese automobile assemblers was significantly higher than the North American and European counterparts in such indicators as assembly productivity, manufacturing quality, product development productivity and lead time, dealer satisfaction, and so on. Although the competitive gap between the Japanese and the Western (particularly US) averages narrowed or disappeared in such indicators as cost, manufacturing quality and product development performance by the early 1990s due partly to appreciation of yen, catch-up efforts of some of the Western auto makers, technology transfers from the Japanese through direct investments and strategic coalitions, slow down of productivity improvements on the Japanese side, the Japanese on average maintained its competitive advantage throughout the 1980s.

Practices and Techniques: The typical volume production system of effective Japanese makers of the 1980s (e.g., Toyota) consists of various intertwined elements that might lead to competitive advantages. Just-in-Time (JIT), Jidoka (automatic defect detection and machine stop), Total Quality Control (TQC), and continuous improvement (Kaizen) are often pointed out as its core subsystems[25]. The elements of such a system include inventory reduction mechanisms by Kanban system; levelization of production volume and product mix (heijunka); Reduction of "muda" (non-value-adding activities), "mura" (uneven pace of production) and muri (excessive workload); production plans based on dealers' order volume

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[25] TQC emphasized clarification of quality goals, communication of the goals to the shop floor, involvement of all the employees, education of shop floor supervisors, diffusion of quality and cost consciousness, making good product the first time (tsukurikomi), cross-functional coordination, coordination with suppliers and dealers, smooth implementation of model changeover, and so on.

(genryo seisan); reduction of die set-up time and lot size in stamping operation; mixed model assembly; piece-by-piece transfer of parts between machines (ikko-nagashi); flexible task assignment for volume changes and productivity improvement (shojinka); multi-task job assignment along the process flow (takotei-mochi); U-shape machine layout that facilitates flexible and multiple task assignment, on-the-spot inspection by direct workers (tsukurikomi); fool-proof prevention of defects (poka-yoke); real-time feedback of production troubles (andon); assembly line stop cord; emphasis on cleanliness, order, and discipline on the shop floor (5-S); frequent revision of standard operating procedures by supervisors; quality control circles; standardized tools for quality improvement (e.g., 7 tools for QC, QC story); worker involvement in preventive maintenance (Total Productive Maintenance); low cost automation or semi-automation with "just-enough functions); reduction of process steps for saving of tools and dies, and so on[26].

The human-resource management factors that back up the above elements include stable employment of core workers (with temporary workers in the periphery); long-term training of multi-skilled (multi-task) workers; wage system based in part on skill accumulation; internal promotion to shop floor supervisors; cooperative relationships with labor unions; inclusion of production supervisors in union members; generally egalitarian policies for corporate welfare, communication and worker motivation[27].

Parts procurement policies are also pointed out often as a source of the competitive advantage: relatively high ratio of parts out-sourcing; multi-layer hierarchy of suppliers; long-term relations with suppliers; relatively small number of technologically capable suppliers at the first tier; subassembly functions of the first-tier parts makers; detail-engineering capability of the first tier makers (design-in, black box parts); competition based on long-term capability of design and improvements rather than bidding; pressures for continuous reduction of parts

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[26] For standard explanations of the production system at Toyota and other effective Japanese auto makers of the 1970s and 1980s, see, for example, Ohno (1978), Nihon Noritsu Kyokai, ed. (1978), Shingo (1980), Schonberger (1982), Monden (1983, 1993), Imai (1986), Toyota Motor Corporation (1987), Womack et al. (1990), and so on.

[27] For human resource management and labor relations of the post-war Japanese auto makers, see, for example, Koike (1977), Yamamoto (1980), Cusumano (1985), Totsuka and Hyodo, ed. (1990), Nomura (1993), Asanuma (1994), etc.

price; elimination of in-coming parts inspection; plant inspection and technical assistance by auto makers, and so on[28].

It is important to note at least the following points in interpreting the above basic facts. First, as summarized in table 2, many of the factors described above are capabilities that are specific to certain production processes (e.g., final assembly, machining, stamping). When analyzing manufacturing capability of the automobile production system as a whole, one has to identify the generic patterns that lie behind the process-specific capabilities. Second, as indicated in table 2, it should be noted that many of the manufacturing capabilities of the Toyota-style production systems were adopted directly, or with modifications, from the Ford system or Taylor system of the Western companies[29]. Thus, the dichotomy view that Toyota production system is a complete antithesis of Ford system and/or Taylorism seems to be utopian and misleading. Most of the capabilities described above were gradually developed in the post-war Japan. Also, many of the Western auto makers, as well as US and European transplants of the Japanese makers, learned or adopted some of these factors systematically from the effective Japanese makers during the 1980 in order to catch up with their manufacturing performance[30]. This seems to indicate that the set of capabilities of the effective Japanese makers were a product of the post-war history, rather than something inherent in the Japanese culture or society.

3.2 Reinterpreting the Production Capability

From the information's point of view, the production capability of the effective Japanese auto makers, illustrated above, can be summarized as *dense and accurate information transmission between flexible (information-redundant) productive resources*. The density of information transmission from the process to the materials leads to high productivity and short throughput time at the same time, while accurate information transmission from the product design to the product.

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[28] See, for example, Sei, Omori and Nakajima (1975), Asanuma (1984, 1989), Matsui (1988), Oshima, ed., (1987), Nishiguchi (1989, 1993), Cusumano and Takeishi (1991), Clark and Fujimoto (1991), Takeishi, Sei and Fujimoto (1993), Fujimoto (1994a), etc.

[29] See, for example, Fujimoto and Tidd (1993).

[30] See, for example, Shimada (1988), Suzuki (1991), Kenny and Florida (1992), Abo, ed. (1994), Fujimoto, Nishiguchi and Sei (1994), etc.

Table 2 Patterns of Manufacturing at Effective Japanese Auto Makers in the 1980s by Processes: An Ideal Type

process	layout	dedicated/ mixed	cycle time	lot size	automation	material handling	worker	reduction of "muda"	reduction of throughput time	quality improvement	flexibility to variety
final assembly	product layout continuously moving assembly line (Ford system)	platform: dedicated or mixed variation: mixed	typically 1 to 2 minutes fine-tuned to sales volume (in theory)	typically 1 to several dozens *mixed model*	deliberately kept to low level power assists, simple robots. *low cost automation*	body: continuous conveyer line (Ford system) parts: *Kanban,* synchronized delivery, etc.	within cycle time: *multi-parts tasks,* but few group works between cycle times: *multi-model tasks* long-term: *rotation* and *multi-skilling*	moving assembly line reveals line imbalance *Shojinka:* flexible task assignment for higher value adding time ratio	*relatively short assembly line* with ordinary line speed *reduction of line stops and reworks*	*doing right things the first time* *self inspection* *Andon and line stop cord (visualizing problems)*	general-purpose tools and equipment *multi-task assembly workers* relatively few common parts
body spot welding	product layout tact assembly line (intermittent)	platform: dedicated or mixed body type: mixed	typically 0.7 to 2 minutes	typically 1 to several dozens	high ratio of automation (robots) *low cost automation*	body: shuttle conveyer line parts: *Kanban,* synchronized delivery, etc.	mostly indirect or semi-direct work (monitoring, maintaining, inspecting, material handling, etc.)	reduction of machines' down times	*reduction of line stops and reworks*	*self maintenance* *Poka-yoke* (fool-proof devices)	mixture of fixed automation and robots flexible jigs
body stamping	product layout (tandem press) batch flow line	*mixed* (with set-up change)	typically less than 10 seconds	typically less than 1000 (rather small lot)	high ratio of automation general purpose equipment	on both ends: inventories in-line transfer: piece-by-piece (automated)	operators participate in set up, inspection and maintenance	*reduction of set-up times* with ordinary machine speed	reduction of coil and panel inventories reduction of # of shots	quality of dies *Poka-yoke* transfer press	*small lot set up changes*
engine machining	product layout (Detroit-type intermittent transfer machine)	dedicated to an engine family	typically 0.5 to 1 minutes	large lot or no change	high ratio of fixed automation	on both ends: inventories in-line transfer: piece-by-piece (automated)	operators participate in set up, inspection and maintenance	reduction of machines' down times	fast transfer between machines	*self maintenance* *Poka-yoke* automated inspection	low flexibility quick set up change of tools
low speed parts manufacturing	product layout, dense *(U-shape)*	dedicated or mixed	typically 0.5 to 1 minutes	large lot or no change	semi-automation *Jidoka* (automated machine stop)	in-line transfer: piece-by-piece (manual) *Kanban* method on both ends	an operator handles multiple machines in the line *(Takotei-mochi)*	reduction of machines' waiting times *Shojinka* for volume changes	no inventory in the line reduction of inventory on both ends	*Jidoka* visualizes quality problems. *Poka-yoke* *self maintenance & inspection*	flexible equipment quick set up change of tools
overall	product layout piece-by-piece flow	rather mixed	depends on technology and market	rather small lot	depends on technology *low cost automation*	conveyer lines wherever possible; *Kanban* as a second best choice (invisible conveyer)	*multi-tasking* and *multi-skilling* stable employment, broad job description, training, etc., as background	systematic reduction of non-value adding time (muda) by *multi-tasking, supervisors' initiatives,* etc.	systematic reduction of inventory and throughput time *(JIT)* for problem visualization	*improvements at all levels (TQC, TPM)* with *Kaizen* initiatives by supervisors,small group activities, suggestions, etc.	flexibility for *small lot high variety production* aggregate volume per line is still large

Higher Productivity and Shorter Throughput Time: The Toyota-style production system focuses on reduction of the time when information transmission is not happening (i.e., non-transmission time) on both sender and receiver side. Let us take an example of a labor-intensive process, where trained workers are the senders and works-in-process are receivers of the value-carrying information. The system aims at low levels of non-value-adding time on the worker side (e.g. waiting time) on the one hand, and non-value-receiving time on the work-in-process side (e.g. inventory) on the other hand. Elimination of unnecessary non-transmission time is particularly emphasized. In essence, what Toyota production system defines as "muda" is unnecessary non-transmission time, which includes inventory, over-production, transportation and defects on the information receiver side, and waiting and unnecessary motions on the sender side[31].

Thus, the ideal system for Toyota-style production resembles a network in which information continues to be transmitted and received between the nodes without much intermission. Such a system with a high-density of information transfer between productive resources, is called "lean" by some authors, as it has a low level of "fat" called non-transmission time[32].

In order to approach to the lean situation, some principles of information handling are applied to the system: those of "receiver first," transmission density, information redundancy, and regularity (figure 7.a).

(1) *Design the system from the information receiver side first.* The production system is deigned from the information receiver side, or from the downstream of the information flows. First, the pace of the entire production process (i.e., cycle time) is set based on the demand of the ultimate information receiver: final customers or dealers. This means minimizing the finished goods inventories. Second, the pace of production (i.e., information transfer) at the upstream is determined by the pace of the downstream process: the principle of Just-in-Time and Kanban. Third, efforts for rationalizing the process flow (i.e., the information receiver side) precedes those for rationalizing the

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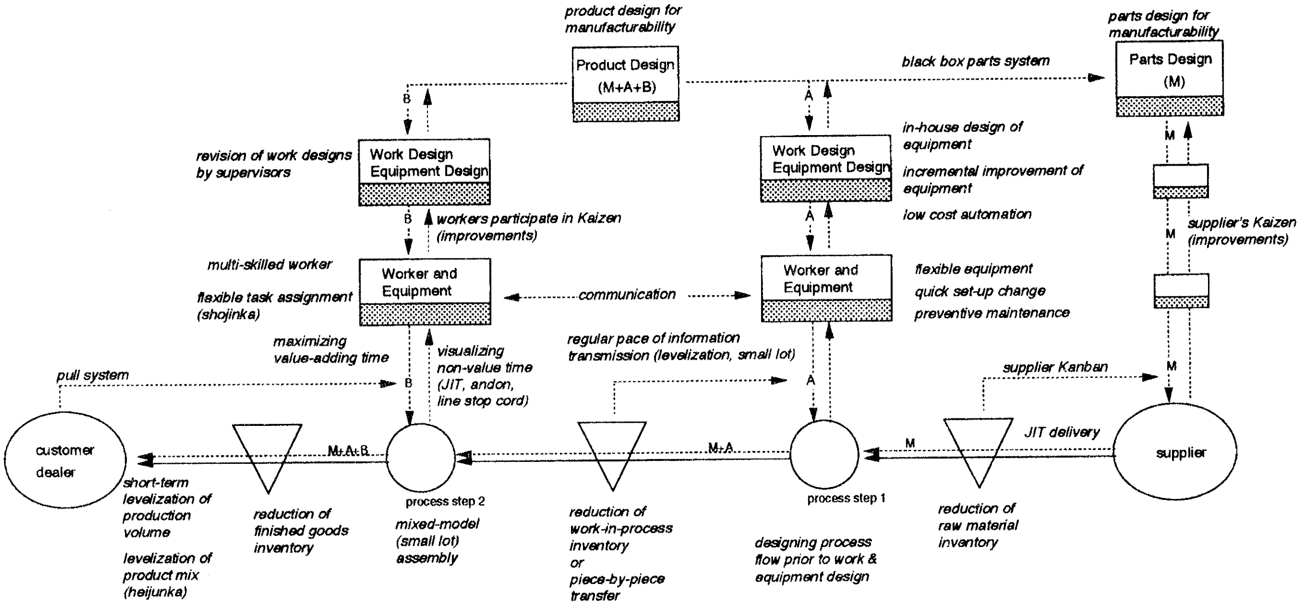
[31] See, for example, Ohno (1978), p. 38.

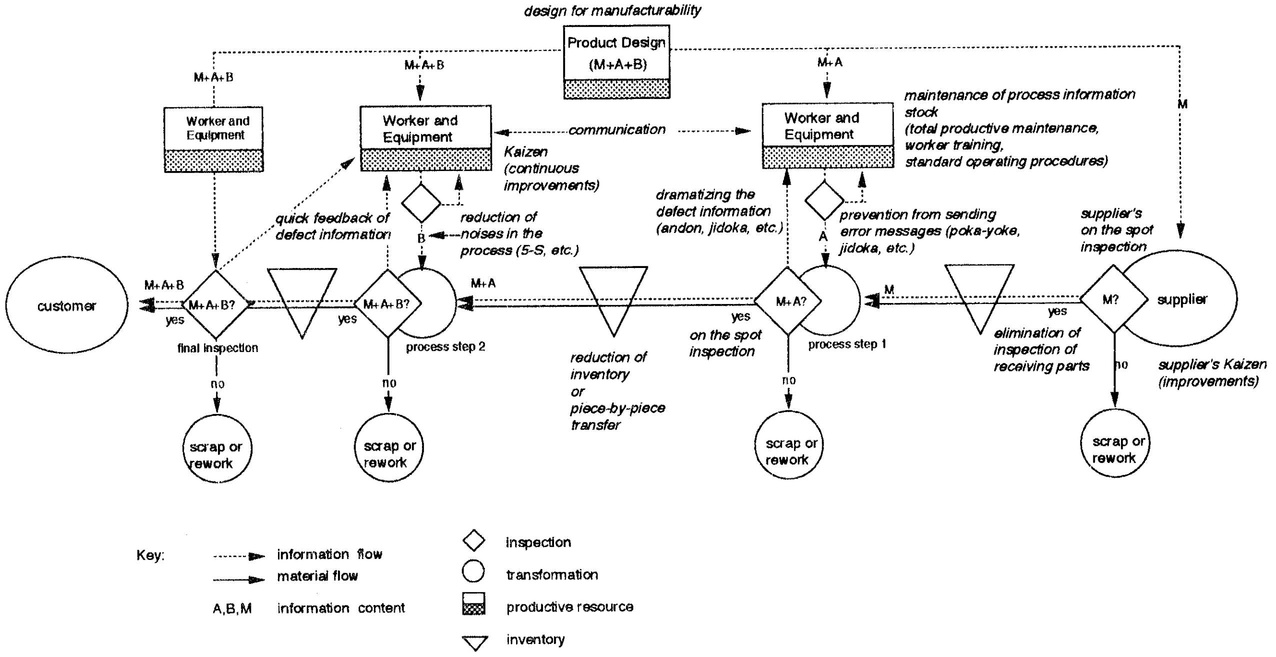
[32] Womack, Jones and Roos (1990).

Figure 7 Static Production Capability of Effective Japanese Auto Makers

a. Capabilities in Productivity and Throughput Time: The Dense Information Network



b. Capabilities in Quality



operations at each process step (i.e. the information source side)[33]. For example, reduction of throughput time by process synchronization, reduction of in-process inventory, product-focused layout along the material flows, piece-by-piece transfer of work-in-process, and so on, precedes improvements in factor productivity. In other words, the efforts to reduce non-value-receiving time on the process flow side tend to precede the efforts to reduce non-value-sending time on the operation side at each process step.

(2) *Give priority to density of transmission rather than speed of information.* It was argued, in section 2.5, that factor productivity can be enhanced either by increasing density of information transmission or by speeding up the transmission itself. The Toyota-style production system has given a clear priority to the former. In other words, taking out non-value-adding time (muda) was much more important than speeding up each individual value-adding operations. For example, Toyota's plant managers would emphasize reduction of set-up time in the press shop rather than increase in the number of stamping strokes per hour; reduction of air-cutting time in machining operations rather than increasing cutting and feeding speed; reduction of waiting time by giving multiple tasks to each assembly worker rather than speeding up the line speed and the assembly motions[34]. Interestingly enough, the latter tended to be emphasized in the traditional Fordistic factories of the 1970s, which was oriented to the "speed-up" and technology-driven approach of mass production. The Toyota-style approach, on the other hand, often brings about significant productivity increase without introducing new production technologies.

(3) *Information redundancy is allowed as long as it enhances transmission density.* As described in section 2.5, redundancy of information stored in a given productive resource may mean flexibility, but additional or duplicated investment on equipment or human resources would result (e.g., overlapped multiple-job training for permanent work force).

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[33] See, for example, Shingo (1980).

[34] It is possible, however, that the view of industrial engineers and that of production engineers on this priority is very different within, for example, Toyota. The literature about Toyota's production system has been written predominantly by industrial engineers, but this does not necessarily mean that industrial engineers always dominated the plant management. Further empirical investigation is needed on the cross-functional power relations within Toyota factories.

However, the Toyota-style system allows, or even facilitates, such redundancy if it contributes to higher density of information transfer in the operation. Multi-skilled workers, job rotation, flexible stamping process with quick die changes, and flexible welding jigs and robots are the examples of information redundancy or duplication in the productive resources.

(4) *Regular pace of information transfers:* When the information system is designed by the "receiver first" principle, the production pace would be determined by customer demands, and process flow will be rationalized first (e.g. inventory reduction). This, however, becomes constraints against improving productivity at each stations, because it tells the information senders (e.g. worker and machines) precisely when they have to transmit the information. Flexibility (information redundancy) of the senders may alleviate the constraints, but another measure is to make the transmission timing as regular as possible like pulses. In the production term, this is called "levelization" (heijunka).

Higher Conformance Quality: Seeing production as information transmission from the process to the materials, we may illustrate the typical pattern of capability for high conformance quality as follows (figure 7.b):

(1) *Emphasis on the information source side*: Contrary to the case of productivity and throughput time, conformance quality control system is designed from the information sender side. That is, the system is designed so that the information sources (e.g. workers and equipment) do not make transmission errors in the first place. This notion of "do right transfer the first time" (tsukurikomi) contrasts with traditional quality control system that emphasizes optimal deign of inspection on the information receiver side. Many of the techniques and practices that are prevalent in the effective Japanese auto makers are consistent with this "information source first" concept: making the transmission of error message physically impossible by certain fool-proof mechanisms built into equipment (e.g., poka-yoke, jidoka); eliminating sources of the "noise" in the production process by giving the shop floor order, clarity and cleanliness (e.g., 5-S campaign); preventive maintenance of information stored in equipment and workers (e.g., Total Productive Maintenance, training of workers); improvement of equipment

and work methods in the information source (e.g., rout-cause analysis, 5-why approach to action plans); product designs that is robust against the noise (e.g., design for manufacture, Taguchi method)

(2) *Quick feedback of defect information:* Once the transmission errors happen, they have to be detected and proper remedies have to be implemented. Effective auto makers tend to reduce lead time between fabrication and inspection, and thereby make information feed back cycles quick. On-the-spot inspection, in which direct workers (including team leaders) inspect what they just made before transferring it to the downstream step is a typical example. Another application of this concept is to let parts suppliers inspect their own parts and to eliminate inspection of incoming parts. Reduction of cycle inventory and piece-by-piece transfer of work-in-process between process steps also reduce lead time between fabrication and inspection.

Procurement Policy: Although supplier policy is not the main theme of this paper, it should be noted that capability building of the suppliers, rather than short term performance, has been much emphasized by the effective auto makers. As a result, suppliers' capability of subassembly, detailed component design, quality control, short throughput time, and continuous improvements were developed as a package mainly in the 1960s and 70s[35]. Thus, with or without intention, the auto makers made each of the first-tier suppliers replicate their capabilities and develop its own intra-firm network of information assets, which turned out to be effective to better competitive performance of the auto makers.

3.3 Basic Facts in Product Development

Let us now turn to basic facts in product development of the Japanese auto makers in the 1980s. Clark and Fujimoto (1991), analyzing data from 29 product development project at 20 Japanese, US and European auto makers, found significant inter-firm and inter-regional differences in both performance and practices.

Performance: Three performance indicators, product development productivity, lead time and total product quality, were measured. Significant inter-regional differences were

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[35] See, for example, Nishiguchi (1989, 1993), Cusumano and Takeishi (1991), and Fujimoto (1994a).

found in the former two. In development productivity (measured by hours worked per project, adjusted for project content), the Japanese projects were on average nearly double as efficient as the U.S. and the European projects. In development lead time (measured by time elapsed from concept study to start of sales, adjusted for project content), also, the Japanese projects were on average about year faster to complete a project than the Western cases (4 years versus 5 years)[36].

In total product quality (measured by total product quality index, which is a composite of such indicators as total quality, manufacturing quality, design quality and long-term market share), however, no clear regional pattern was detected. The Japanese companies included both top-rank players and bottom-rank ones, and so were the European and American group. The top-rank Europeans turned out to be high-end specialists. Thus, what mattered in total product quality was inter-firm differences, rather than the Japan effect in general.

Practice and Organizations: Clark and Fujimoto (1991) also summarized product development capabilities of some effective Japanese car makers as follows:

- *Black Box Parts:* The Japanese auto makers tended to use black box parts practice, in which suppliers do detailed component engineering based on specifications provided by the auto makers, more often than the Western counterparts. In this way, the Japanese companies tended to keep the size of their own development projects compact by letting parts suppliers do a significant part of the engineering jobs. The compactness of the projects, in turn, contributed to shorter lead time and higher development efficiency by simplifying the task of project coordination to a manageable level. Besides, black box parts contributed to significant product cost reduction by allowing the suppliers to design parts with high manufacturability.
- *The Impact of Production Capability:* The Japanese auto makers tended to apply their capabilities in manufacturing to critical activities in product development, such as prototype fabrication, die development, pilot run, production start-up, etc., which, in turn, contributed to improvement in overall performance of product development. For example, application

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[36] Preliminary results of the second round survey conducted in 1993, however, indicates that the US makers on average caught up with the Japanese in both lead time and development productivity. Presentation by Clark, Ellison and Fujimoto at ORSA/TIMS meeting in Boston, April 1994.

of just-in-time philosophy to body die shops seem to explain part of the reason why die development lead time of the average Japanese projects is much shorter than that of the Western projects.

- *Stage Overlapping and Intensive Communication:* The Japanese projects tended to overlap upstream stages (e.g. product engineering) and downstream stages (e.g. process engineering) more boldly than the American and European projects in order to shorten overall lead time[37]. The Japanese practices indicated that the overlapping approach can effectively shorten lead time only when it is combined with intensive communications between the upstream and the downstream. Effective overlapping also needs capabilities of both upstream and downstream people to cope with incomplete information, as well as flexibility, mutual trust, and goal sharing between the two stages. Without such conditions, stage overlapping is likely to result in confusion, conflict, and deterioration in product development performance (Compare the two cases in the figure).
- *Broad Task Assignment:* The study of Clark and Fujimoto (1991) also found that, the lower the specialization (i.e. the broader the task assignment of each engineer), the faster and more efficient the projects tended to be. Many development organizations (mostly Western) seem to have been suffering from the over-specialization syndrome, while some others (mainly Japanese) appear to benefit from lower levels of specialization without losing technological expertise.
- *Heavyweight Product Manager:* The research also revealed that the effective Japanese firms which achieved high performance in lead time, productivity and product integrity simultaneously were those which combined powerful internal integrator (i.e. project coordinator) and external integrators (i.e. product concept champion) in one role. Clark and Fujimoto called this role heavyweight product manager -- a combination of strong project coordinator and strong concept leader [38]. It is important to note that, even among the Japanese companies, there were significant difference in both total product quality and

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[37] This practice is called simultaneous engineering or concurrent engineering since the late 1980s.

[38] See Clark and Fujimoto (1990, 1991) and Fujimoto (1989, 1991). For economic interpretation of this phenomenon, see Itoh (1992).

"heaviness" of product managers, and that the two indicators tended to be correlated positively.

Summarizing the above findings, Clark and Fujimoto concluded that a certain pattern consistency of the overall development processes and organizations, rather than individual techniques and technologies, was the key to effective product development in the 1980s.

3.4 Reinterpreting the Product Development Capability

From the information point of view, the product development capability of the effective Japanese auto makers may be summarized as follows (figure 8)[39].

(1) Direct and continual flows of information from market to concept generation units, which creates product concepts proactively, rather than reactively.

(2) Continual and cumulative elaboration of product concept information throughout the project period for flexible adaptation of the concepts to the changing market needs.

(3) Direct and continual internal flows of information among the concept generation units, product planning units, and product engineering units throughout the entire period of product development. Since the product concepts cannot be fully articulated by product plans or other documents, direct interaction between concepts and designs is of particular importance.

(4) Early information exchange to bring downstream experience to the upstream effectively and to reveal conflicts during the early stages. This is expected to lower the subsequent information processing work load due to design changes and to shorten overall lead time.

(5) Early information exchange between the auto makers and suppliers. many of the first-tier suppliers, with detailed engineering capabilities, work closely with the auto makers by maintaining frequent communications of component design information.

(6) Overlapping problem solving: downstream problem solving cycles start before upstream cycles are completed in order to shorten lead time. In order to do this effectively, upstream and downstream have to be integrated through the early release of preliminary information in both directions.

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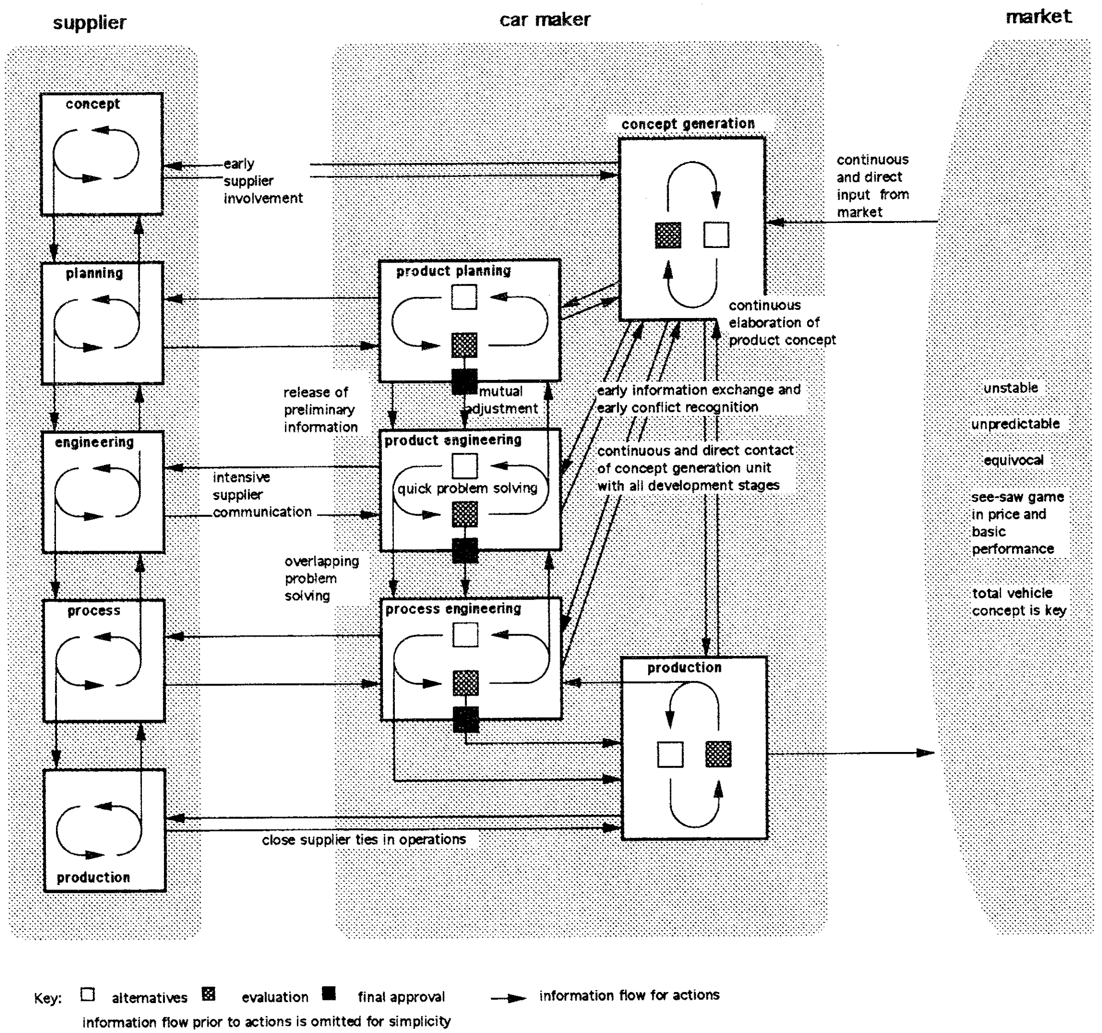
[39] See, also, Fujimoto (1989, 1993) and Clark and Fujimoto (1991).

Figure 8 Information Patterns of Product Development at Effective Japanese Auto Makers



Source: Adopted from Clark, Kim B., and Takahiro Fujimoto. Product Development Performance. Harvard Business School Press, 1991, p. 291.

(7) Fast problem-solving cycles within each stage in order to respond quickly to continuously changing inputs.

To sum up, the product development capability of effective Japanese auto makers can be characterized by an ability to handle a dense information network, in which information creation and problem solving are conducted in parallel by various organizational units, fast problem solving and feed back cycles are maintained within each unit, and preliminary information is transmitted between information assets as it is created step by step.

3.5 Improvement Capability in Production and Development

Continuous Improvement in Production: Continuous improvement of productivity and quality (Kaizen) is often seen as a core capability of effective Japanese production systems[40]. The idea of factories as learning laboratory is adequate here[41]. The elements of both Just-in-Time and Total Quality Control appear to jointly contribute to the improvement capability, although the two systems tend to be formally explained as Two separate systems in the text books[42].

(1) *Revealing the production problems on the spot:* There are various practices that reveal, visualize and dramatize the potential problems to the organizational members. Reduction of inventories in JIT surfaces non-value-adding time of worker and equipment; Jidoka (automatic machine stop against defects) and line stop cord visualize and dramatize the defect problems; Neatness and cleanliness of the shop floor (5-S) makes disorders visible. Above all, "Kaizen mind," or problem consciousness of the workers, supervisors and plant engineers, facilitates quick detection of the problems on the shop floor.

(2) *Quick problem solving at all levels of the plant*: Once the problems are identified, the people who have daily experiences with the causal networks of the shop floor are empowered and equipped with tools for identifying rout causes, finding alternatives and solving the problems. In the effective auto factories, such as Toyota's, supervisors keep

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[40] Imai (1986).

[41] Leonard-Barton (1992b)

[42] Schonberger (1982) explains the core system as a combination of JIT and TQC.

on making and revising operating standard procedures, workers are involved in the suggestion system and small Kaizen groups, and maintenance workers and plant engineers constantly patrol the shop floor. Although the supervisors tend to play a pivotal role, all of the above players jointly create and evaluate alternative plans for improvements[43].

(3) *Standardization of problem solving tools:* It is important to note that the tools for improvement and problem solving are highly standardized in the effective TQC adopter, although standards for operations themselves are frequently revised. So called "QC stories" and "seven tools of quality control" prevailed among the TQC participants. This kind of standardization facilitated diffusion and retention of improvement skills and experiences into the employees. The diffusion of standard problem solving tools is particularly important because actual manufacturing problems on the shop floor tend to be ill-structured and ambiguous. Thus, artificially imposing standardized problem solving framework on the real problems in the plant facilitates organizational learning and improvements.

(4) *Quick experimentation and implementation:* At Toyota, implementation of revised production methods often precedes proposals or suggestions: Changes are experimented and implemented first, and then they are proposed through the suggestion system or regular improvement programs (This may explain why there are so many suggestions and why their acceptance ratio is high at Toyota). Thus, experimentation and implementation are often inseparable.

(5) *Retention through knowledge-manual interactions:* The retention mechanism of the effective makers depends on both manuals and human resources. At a given point in time, Toyota's factories may look quite Tayloristic, in that they have massive accumulation of standard operating procedures. Over time, however, the standards are frequently revised, and the revisions are done not by expert industrial engineer but shop floor supervisors: what Cole and Adler (1993) call "democratic Taylorism." At the same time, stability of the work force also helps the retention of new methods stored in

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[43] For the role of supervisors and team leaders in continuous improvements, see Nemoto (1992).

collective human memories. Thus, whether Toyota-style system depends on manuals or tacit knowledge does not seem to be a relevant question because it depends on both; what matters seems to be a rapid and two-way conversion of information between tacit knowledge and formal written procedures[44].

Product Renewal: In the area of product development, rapid product renewal and expansion of products have been recognized as the main improvement capability[45]. High development productivity seems to have contributed to this frequent changes in product designs[46]. In other words, the capability of high development productivity tended not to be used directly for cost reduction, but to increase the pace of product changes while matching the unit R&D cost with competitors.

Also, rapid transfer of product design information across the projects was identified as one of their core capabilities in product improvements[47]. Continuity of product managers and working engineers between old and new projects also helped inter-project knowledge transfer. Overall, effective Japanese product development of the 1980s tended to rely on carry-over of people, rather than that of component designs, between the projects for consistent improvements over time.

Similarity of Development and Production Capabilities: As described above, both static and improvement capabilities of the effective Japanese auto makers in production and in product development have much in common: They are characterized as dense information networks, in which value-carrying information is continually transmitted, absorbed, and renewed in each developmental-productive resource. Cycles of information processing and problem solving are short in both cases. Information stocks are incrementally revised as the resources receive new information inputs, and the revised information is immediately transferred to other resources. Thus, from the information point of view, the basic patterns and principles of production capability and development capabilities seem to be similar to each other (table 3)[48].

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[44] Nonaka (1993)
[45] Sheriff (1988)
[46] Clark and Fujimoto (1992)
[47] Nobeoka (1993)
[48] See Clark and Fujimoto (1991, Chapter 7) .

Table 3 Similarity of Patterns of Production and Product Development Capabilities

Production	Product Development
- frequent set-up changes	- frequent product renewals
- short production throughput time	- short development lead time
- reduction of work-in-process inventory between production steps	- reduction of informational inventory between product development steps
- piece-by-piece transfer (not in batch) of parts from upstream to downstream	- frequent transmission (not in batch) of preliminary information from upstream to downstream
- quick feedback of information on downstream problems	- early feedback of information on potential downstream problems
- quick problem solving in manufacturing	- quick problem solving cycle in engineering
- upstream activities are triggered by real time demand of downstream (pull system)	- upstream activities are motivated by market introduction date in downstream
- simultaneous improvement in quality, delivery, and productivity	- simultaneous improvement in quality, lead time, and development productivity
- capability of upstream process to produce saleable products in the first place	- capability of development (i.e. upstream) to produce manufacturable products in the first place
- flexibility to changes in volume, product mix, product design, etc.	- flexibility to changes in product design, schedule, cost target, etc.
- broad task assignment of workers for higher productivity	- broad task assignment of engineers for higher productivity
- attitude and capability for continuous improvement and quick problem solving	- attitude and capability for frequent incremental innovations
- reduction of inventory (slack resources) forces more information flows for problem solving and improvements	- reduction of lead time (slack resources) forces more information flows across stages for integrated problem solving

Source: Adopted and modified from Clark, Kim B., and Takahiro Fujimoto. Product Development Performance. Harvard Business School Press. 1991: p. 172.

Having described reinterpreted the stylized facts of the static and improvement capabilities, let us now turn to the evolutionary capability of the Japanese auto makers.

4. Capability Building in Toyota-style Development-Prodiction Systems

This section presents some cases of evolution or system emergence and reinterpret them. Our main focus is Toyota Motor Company, known as one of the most competitive auto maker of the 1980s. Since the space is limited, only brief summaries of each case are shown here[49].

Before analyzing the patterns of historical evolution, let us first summarize some seemingly "stylized" facts based on the empirical work conducted through the early 1990s.

(1) Evolutionary Process: So called Toyota style system was not developed all at once by rational strategic decision making, but gradually evolved during he post-War period (or even since the 1930s)[50].

(2) Regional Specificity: During the 1980s, the Japanese auto makers tended to cluster in terms of competitive performance and practices in many cases, and outperformed the US and European firms on average[51].

(3) Individual Firm Specificity: Despite the regional effect,. there were significant differences in performance and practices among the Japanese auto makers in many other aspects. Thus, region-specific patterns and firm-specific patterns in production-development capabilities and performance coexisted during the 1980s[52].

(4) Hybridization: The Toyota-style system has not been a totally unique and original production system that challenges traditional Ford system, despite the sharp contrasts between the two system as of the 1980s. Toyota system has adopted various elements of Ford system and hybridized them with their indigenous system and original ideas. There is an obvious continuity between the two system[53].

Thus, it can be predicted at this point that neither rational-strategic decisions nor environmental determinism alone would be able to explain the overall evolutionary process of this system of development-production capabilities. Based on the above argument, the rest

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[49] For further details, see, for example, Fujimoto and Tidd (1993) and Fujimoto (1994a, 1994b, 1994c).

[50] See, for example, Fujimoto and Tidd (1993).

[51] See, for example, Womack, Jones and Roos (1990) and Clark and Fujimoto (1991).

[52] See, for example, Cusumano (1985) and Clark and Fujimoto (1991).

[53] See, for example, Ohno (1978), Abernathy, Clark and Kantrow (1983), Shimokawa (1991), and Fujimoto and Tidd (1993).

of this section explores historical evolution of various aspect of the system such as Just-in-Time, mechanisms for productivity improvement, multi-tasking, flexible production, Total Quality Control, suppliers' design capability, and heavy-weight product manager system.

4.1 Capability Building for Just-in-Time

The origin of Just-in-Time system is a complex combination of entrepreneurial visions, knowledge transfer from other firms and industries, environmental constraints, and rational behaviors.

Entrepreneurial Vision: The idea and slogan of "Just-in-Time" was created and advocated by Toyota's founder-entrepreneur Kiichiro Toyoda during the 1930s. Although concrete methods (e.g., "super market" system, "Kanban" system) did not exist, Kiichiro had strongly insisted that the downstream should order just enough quantity that it needed. When Kiichiro started the automobile business, he first posted the word "Just in Time" on the wall, and told his subordinates to receive just twenty engine blocks in the morning and nothing more if we needed twenty that day. Kiichiro was frequently walking about the factory and threw away anything above what was needed[54].

. Transfer from Ford: Toyota's Just-in-Time and Ford system of the early days (the era of Highland Park experiments) had much in common in that both pursued synchronization of upstream and downstream processes[55]. Ford system synchronized the work stations by physically linking them by continuous conveyers; Just-in-Time created pressures for synchronization by eliminating buffer stocks between the stations (i.e., invisible conveyer line). Although it was after the World War II that Toyota introduced conveyer systems on a large scale, it likely that Kiichiro had Ford system in his mind when he advocated the Just-in-Time idea.

Transfer from Textile: Another important source of Toyota Production System seems to be production experiences of Toyoda Spinning and Weaving, which was transferred by Taiichi Ohno, the de-fact inventor of JIT. When Ohno was working as supervisor at the spinning factory of this textile company, he realized that its rival, Nichibo (Japan Spinning)

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[54] Toyota Motor Corporation (1978), pp. 64.

[55] See Shimokawa (1991).

was outperforming Toyoda in productivity through a bench marking study. Further studies revealed that the production system of Nichibo was very different from that of Toyoda Spinning and Weaving. Toyoda had separate buildings by process steps; Nichibo had adopted the line layout along the process flow. Toyoda moved yarns in large lots; Nichibo conveyed them in small lots. Toyoda had emphasized skills of rework (yarn tying) at the downstream step; Nichibo had emphasized making good yarns at the upstream and eliminating rework at the downstream. In this way, Ohno obtained some of the key ideas of Toyota Production System, including product-focused layout, small-lot production, and "doing things right the first time", thorough the bench marking study in the textile industry. When Ohno moved to Toyota Motor Manufacturing in 1943, his first impression was that it would be easy to raise productivity of the automobile business by three to five times by simply introducing the production system adopted by Toyoda Spinning and Weaving[56].

Historical Imperatives - The 1950 Crisis: Although productivity increased rapidly, Toyota faced a crisis during the 1948 - 49 recession. With many finished goods inventories piling up, Toyota, on the verge of bankruptcy. It also fired 2000 employees, which triggered a series of strikes by the union[57]. Two lessons that Toyota was forced to learn from this crisis, among others, were "limited volume production" (genryo seisan) and the human resource management with long-term stabilization of employment.

> We got a lesson from the crisis that productivity increase and cost reduction had to be accompanied by "limited volume production", which meant that we had to produce just enough to sell and just when we could sell. We learned that productivity increase for the sake of itself was no good, and that we should not simply imitate the American style mass production[58].

Diffusion of Kanban System: Although the idea of Just-in-Time was created by Kiichiro Toyoda in the 1930s, Kanban system, a formal mechanism that materialized the idea, started in the late 1950s under the leadership of Taiichi Ohno[59]. The system was

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[56] Wada (1994) also points out that there was another source of the synchronized production idea from the prewar aircraft industry.

[57] For labor movements at this stage, see, for example, Cusumano (1985, chapter three).

[58] Interview with Ohno by Shimokawa and Fujimoto, July 16, 1984.

[59] See Ohno (1978).

originally called “supermarket system”, in that the downstream station had to come to the upstream to pick up just enough parts, whereas the latter had to produce just enough to replenish what was taken by the former[60] . The system, which linked the upstream and the downstream by standardized returnable containers and reusable slips called Kanban, had already been articulated around 1949, according to Ohno, but the Tax Office did not allow this arrangement until the mid 1950s on the ground that the system did not document accounting records for each transaction.

Unlike TQC, diffusion of JIT was rather slow, as it started as Ohno's informal experiments, as opposed to a company-wide movement. Initial experiment were made only where Ohno directly supervised. He introduced Kanban system first in the body welding line, in which small lot production was the key. Ohno told the shop floor people, “Kanban is like money: If you take out parts without Kanban, you are stealing the parts.” Kanban system was then introduced to the upstream press operations, and then such component as engine oil pans and tappet covers. It was also installed at Motomachi assembly plant upon its completion in 1959. In the early 1960s, Ohno became the main plant manager, when he introduced Kanban to casting, forging and heat treatment, the most difficult processes for small lot production[61] . In 1962, Kanban was authorized and adopted at the company-wide level. In 1965, Toyota formally started diffusion of the system to the suppliers.

4.2 Capability Building for Productivity Improvement and Multi-Tasking

Kiichiro's Vision and Bench Marking: In September 1945, soon after the end of the World War II, GHQ (General Headquarters) approved Totota's production of trucks. Relying mostly on old equipment dated back to the 1930s, Toyota's production activity was severely limited by financial and capacity constraints. Its annual production finally surpassed the prewar peak (about 16,000 units) in 1953[62] . It is remarkable that, in this desperate situation, Kiichiro Toyoda already had future competition with the Western auto makers in mind. According to Taiichi Ohno, Kiichiro launched an ambitious goal of catching up with the

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[60] The term “Kanban” was coined as a catchy word when Toyota challenged Deming Award in 1965.

[61] Interview with Ohno by Shimokawa and Fujimoto, July 16, 1984.

[62] Cusumano (1985, pp. 61 and 75).

productivity level of the American auto makers within three years[63]. Ohno estimated the productivity level of the American makers to be 10 times as high as that of Toyota right after the war[64]. Although Kiichiro's goal was too ambitious, Toyota did increase productivity by 10 times between 1945 and 1955 in some of the core operations, according to Ohno. When Ohno visited Ford and GM engine plants in 1956, he found that the American plants had not improved productivity since the 1930s, and that productivity at Toyota's engine plant at that time had already be higher than them in gross terms (i.e., unadjusted for product and process characteristics).

It is important to note that GM and Ford, establishing their knock down assembly plants in the mid 1920s, virtually dominated the Japanese motor vehicle markers around 1930 with the combined market share of over 90%, until the Japanese government enforced a protectionistic law in 1936. It is likely that the memory of the dominance of the American mass producers made Kiichiro and other Toyota managers continue bench-marking and set high operational targets to compete with the imaginary rivals in America, even in the middle of fully protected domestic market in between the 1930s and 50s[65].

Adoption and Modification of Taylorism: The traditional craft system persisted in Toyota's production processes during the 1930s and 40s[66]. Foremen-craftsmen led the team of workers as master and was responsible for production volume and quality. They told their subordinates, "Steal the way in which others are doing", "Learn for yourself by your skin feeling". Workers machined a variety of parts using general-purpose equipment, while sharpening their own cutting tools. Process flows were often disturbed, work-in-process inventories piled up, and lack of balance in machine utilization occurred.

This kind of craft production environments remained even after the World War II, but they were gradually replaced by standardization of operations, product-focused layout, and multi-skilled workers handling more than one standard job. Taiichi Ohno, the champion of

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[63] Interview with Ohno by Shimokawa and Fujimoto, July 16, 1984.

[64] This was based on his estimation around 1935 that the U.S. productivity in spinning operations would have been 9 times as high as that of the Japanese.

[65] See Fujimoto and Tidd (1993) for details of the UK - Japan comparison in this regard.

[66] Toyota Motor Corporation (1978), pp. 92 - 95.

Just-in-Time system, recalls the situation when he was assigned to section head of Toyota's machine shop in 1946[67] .

> The first thing that I did was standardization of jobs. The shop floor of those days was controlled by foremen-craftsmen. Division managers and section managers could not control the shop floor, and they were always making excuse for production delay. So we first made manuals of standard operation procedures and posted them above the work stations so that supervisors could see if the workers were following the standard operations at a glance. Also, I told the shop floor people to revise the standard operating procedures continuously, saying, "You are stealing money from the company if you do not change the standard for a month."

In this way, the shift from craft production to Taylor-type standardization made progress in the late 1940s at least at Toyota's machine shops, despite some resistance from traditional crafts people. It should be noted, however, that the seemingly Tayloristic movement of work standardization at Toyota was accompanied by continuous improvements of the standards themselves. Thus, unlike the Ford system in America, in which work standardization tended to mean freezing of standard operations and vertical separation between single-skilled workers and elite industrial engineers, standardization under Ohno's leadership emphasized continuous improvements at the shop floor[68] . Also, in Ohno's machine shops, work standardization and training of multi-skilled workers were carried out in parallel. In other words, decomposition of craft jobs into standardized tasks and re-combination of the tasks to multi-skilled jobs occurred at the same time. Unlike American Taylorism-Fordism that essentially created single-skilled workers, Toyota in the late 1940s replaced traditional craft jobs with multi-skilled jobs. Overall, Ohno claims that Toyota increased productivity by 5 - 6 times by 1950 while relying mostly on old machines of the 1930s[69] .

Transfer from Textile: It is obvious that Ohno, with his experience in spinning operations, applied the concept of multi-machine work assignment to the automobile industry[70] :

> Improvement of productivity from 1945 to 1950 was relatively easy. For example, there were three or four workers around one machine, particularly when it was an important one, prior to the war. So simply assigning one worker to one machine increased

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[67] Interview with Taiichi Ohno. July 16, 1984, at the headquarters of Toyota Gosei. Interviewer: Professor Koichi Shimokawa of Hosei University and the author.

[68] On the transformation of Ford system from that of dynamic experimentation to a static system of fragmented jobs, see, for example, Abernathy, Clark and Kantrow (1983, Chapter 6), and Shimokawa (1991).

[69] Interview with Ohno by Shimokawa and Fujimoto, July 16, 1984.

[70] Interview with Taiichi Ohno. July 16, 1984, at the headquarters of Toyota Gosei. Interviewer: Professor Koichi Shimokawa of Hosei University and the author.

productivity by three, four times. Workers with craftsmen's mentality resisted to such measures, but labor saving was relatively easy as turnover ratio was very high at that time.

Historical Imperatives - Forced Growth: The introduction of work standardization, centralization of tool maintenance and productivity improvement with low production growth created tensions against the craft-type foremen and machinists. Researchers point out that the militant craftsmen-foremen were played a central role in Toyota's labor conflict in 1950.

Although Toyota increased production capacity in response to the Korean War's special orders of trucks from the U.S. Army (APA) , it carefully avoided adding employees for the expansion, as the memory of the labor crisis was still fresh. Toyota also had to expand the capacity while using the old machines. It is likely that Toyota was predicting fluctuation of production volume along the business cycles, and was trying to minimize the number of permanent work force in order to avoid another firing and strikes.

This prediction turned out to be generally wrong, however. Production started to grow rapidly in the 1950s, and it continued to grow without large recessions until 1990. Toyota, however, maintained conservative recruitment policy. Productivity increased almost automatically by expanding production scale while minimizing increase in the number of workers. Thus the pattern of production expansion without much adding employees, and reduction of finished goods inventory (i.e. limited volume production) was installed at Toyota through its experience of the crisis and the subsequent growth. During the high-growth era of the 1960 and 70s, Toyota absorbed the workload required for the growth by hiring temporary workers, subcontracting out subassembly jobs, prolonging over-time work, and improving labor productivity, but it tended to keep conservative recruitment policy as far as permanent worker were concerned.

4.3 Capability Building for Flexible Production Equipment

Visions for Modified Ford System: Kiichiro Toyoda of Toyoda Automatic Loom started engine research and prototyping on a small corner of its facility around 1931, five years before the protectionist law was launched. Ford and GM were dominating the domestic automobile market then. Kiichiro's business concept at this early stage was as follows:

(1) Develop a 3000 cc class automobile and compete directly with the American models both in price and performance.

(2) Although Toyota learns from American system of mass production, it takes into account situations of the Japanese market that would limit the production volume to only several hundred units per month, and modifies the system accordingly[71] .

Kiichiro's vision to compete directly with Ford and GM was a quite ambitious (even reckless) one considering that it was made when the American knock-down vehicles were still dominating the market. His vision was apparently ignoring the principle of economy of scale and cost curves. On the other hand, Kiichiro did not try to introduce the Ford system directly but to adapt it to the Japanese conditions (small market, bad roads, etc.) both in product and process technology. Kiichiro's vision, although unrealistic at that time, functioned as driving force for Toyota's dramatic productivity improvement in the late 1940s and early 1950s. This seems to demonstrate Kiichiro's "capability of business conceptualization" at this early stage of business development[72] .

Forced Flexibility of Machines: When Toyoda's Kariya Assembly Plant completed in 1936. Its capacity (150 units per month) was quite small compared with a standard American plants[73] . Based on Kiichiro's vision to "match Toyoda's unit cost of producing 20,000 to 30,000 units per year with that of Americans producing several hundred units per year[74] ," Toyoda had to modify the Ford system for small volume production. For example, it replaced a part of body stamping processes with manual jobs in order to save fixed cost for tooling. The size of Koromo plant, established in 1938, was still much smaller than that of average American factories (2000 units per month, 5000 employees). Thus, Toyota continued to select production technologies deliberately, considering the limit of production scale[75] . For example, it purchased only several press machines in the door panel process, where American makers would have installed several dozens of the machines. Toyota also kept its machining operations somewhat flexible by introducing multi-spindle balling and horning machines that were adjustable to design changes, unlike standard Detroit-type machines. It

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[71] Toyota Motor Corporation (1978), pp. 41

[72] See Okouchi (1979).

[73] According to Abernathy (1978, pp. 138), capacity of a standard Ford assembly plant was about 400 to 500 units per 8 hours, or about one minute cycle time, since the mid 1910s.

[74] Toyota Motor Corporation (1978), pp. 60.

[75] Toyota Motor Corporation (1978), pp. 85.

also made the machine shop flat so that its process layout could be changed easily. In this way, the small scale of Toyota's production forced the company to chose flexible production systems deliberately.

Transfer from Machinery Industry: A typical example of simple mechanization in the late 1940s is the case of welding jigs[76] . While Toyota was consigning a part of body welding jobs to a heavy machinery maker its inspectors found that the cabins made by the outside company was more accurate in dimensions than those by Toyota, in which deviations by 5 to 10 millimeters were common. A supervisor of Toyota's welding factory visited this company and found that it had been using jigs for dimensional accuracy. Toyota of those days had neither welding jigs nor production engineering department in charge of making them, so this supervisor had to collect information and make body assembly jigs for himself.

Learning From Ford: Soon after the end of the 1950 labor crisis, Eiji Toyoda and Shoichi Saito, who eventually became leaders of Toyota, went to America and visited Ford's River Rouge Factory and other facilities. Their study of the American automobile factories was intensive and lasted for three months. Their visits were obviously motivated by Toyota's plan to modernize its production facilities. Soon after their return, Eiji and Saito launched a five year plan for modernization of production equipment (1951-1955). The goal of the plan was to replace the old equipment with new one, introduce conveyers and automation, and to expand the monthly production scale to 3000 units. Although Toyota was suffering from a severe shortage of cash, Toyota managed to carry out 4.6 billion yen investment between 1951 and 1955. The equipment introduced during this period included continuous casting lines for engine blocks, 2000 ton press machines, and multiple spot welders. Eiji was particularly impressed by the conveyer system at River Rouge factory, and told his staff to adopt conveyers extensively on his return from America. He also standardize ordered to standardize pallets and containers, which may have facilitated introduction of Kanban system subsequently.

Transfer machines, a typical Detroit-type automation that links a series of single-purpose machine tools by automated transfer devices, was introduced to a part of engine

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[76] Toyota Motor Corporation (1978), pp. 160.

machining process in the late 1950s. The first machine, developed jointly by Toyota and Toyoda Machine Tools, was installed in 1956. Although it is likely that Toyota studied the transfer machines in Detroit, the machines themselves were developed and built by the Japanese companies including Toyota itself.

Historical Imperatives - Shortage of Investment Funds: In the first five years of the post-war restoration, Toyota was forced to increase productivity and achieve the goal of 1000 truck production per month without sufficient funds and equipment. Therefore, the improvements of Toyota's production system during this period tended to rely on such "soft" methods as work standardization, changes in layout and job assignment, as well as investments on relatively inexpensive jigs.

Taiichi Ohno took charge of Koromo assembly plant in 1945. Ohno emphasized factors other than machines as he had observed a large productivity gap between Toyota and the Western makers although they were using similar equipment. Here we find certain philosophies of subsequent Toyota Production System that emphasize mechanisms to reveal problems purposefully, as well as total system improvements rather than mechanization. This may be partly ascribed to insights of Toyota' managers, but it is also likely that the historical imperatives of capital shortage forced the company to de-emphasize mechanization solutions. The concept of low-cost automation and semi-automation for cost effectiveness is still prevalent at Toyota[77].

Product-Focused Layout: Although engine machining factory had already adopted product-focused machine layout (i.e., installing machine tools according to process sequence for a particular product group), transmission and suspension factories had been organized by types of machines (e.g. balling, lathe, milling, grinding)[78]. The level of in-process inventories was high. It took Ohno and his staff two years to convert the layout to product-focused one. As the number of machines increased, machine utilization ratio decreased, but Ohno told his people to disregard this apparent loss[79]. The number of workers was not increased much,

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[77] See, for example, Fujimoto (1993b).

[78] As for the change of machine layout in early Ford system, see, for example, Hounshell (1984), pp. 221 - 222. Wada (1994) points out that the prewar aircraft industry may be another source of the product-focused layout and semi-flow production system.

[79] For example, the number of balling machines increased from 50 to 200. Interview with Ohno by Shimokawa and Fujimoto, July 16, 1984.

however, as Toyota trained multi-skilled workers, who operated multiple machines, often with U-shape layout, along the process flow (i.e., takotei mochi)[80].

In a sense, however, the product-focused layout may be regarded as an incomplete version of Detroit-type automation with fully automated material handling and product-focused machine layout (e.g. transfer machines). While diffusion of transfer machines at Ford was rather limited to high-volume items, the diffusion of process-focused layout at Toyota was widespread[81]. Thus, simply speaking, the patterns of diffusion of mechanization at Ford and Toyota may be contrasted as "incomplete diffusion of complete automation" versus "complete diffusion of incomplete automation." It is likely that the latter approach had more significant positive effects on cost reduction and productivity improvement.

Jidoka: "Jidoka" (Autonomation) consists of machines that automatically detect defects and stop operations, started to be introduced in the late 1960s, according to Ohno[82]. Although the philosophy behind Jidoka originated from Sakichi Toyoda (Founder of Toyota group) earlier in the century, it was sophistication of sensor technology that enabled automatic machine stop mechanisms[83]. The key feature of Jidoka is that the machine simply stops responding to the defect, which dramatizes the problems and forces human interventions, as opposed to automatically making corrective actions. Thus, Jidoka is now recognized as an important mechanism of the organizational learning built into Toyota production system. Whether Jidoka was originally designed for this purpose needs further investigation, though. It may be the case that Jidoka, when it originated, was partly a result of investment saving or lack of advanced automation technology.

4.4 Capability Building for Kaizen and Total Quality Control

Adoption of Suggestion System and TWI from the US Another system of Ford that impressed them was the suggestion system (i.e. workers make suggestions for improvements

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[80] It should be noted, here, that multi-skilled workers are different from traditional crafts people: the former did a series of standardized tasks along the process flow; the latter were all round players who did everything related to their trade regardless of process flow or work standards.

[81] For development and diffusion of Detroit-type automaton, see Hounshell (1994).

[82] For the concept of Jidoka, see, for example, Monden (1983, 1993).

[83] Interview with Ohno by Shimokawa and Fujimoto, July 16, 1984.

on various technical and organizational issues). Soon after they came back to Japan, Eiji and Saito started the "Idea Suggestion System" (soi kufu teian seido) in 1951, which subsequently became a core element of Toyota's TQC (Total Quality Control) and Kaizen (Continuous Improvement) systems. Toyota recognized the suggestion system as a competitive weapon from the beginning:

> In order to survive in the competition with foreign automobiles in future, we have to reduce manufacturing cost by making use of our suggestions (Comment by Saito, 1951)[84]

Another important system that Toyota introduced from America around was formal training of "scientific management" for supervisors, called Training within Industry (TWI)[85]. TWI, introduced to Toyota in 1951, was applied to general foremen (kakari-cho) and managers above them. Among others, TWI included training of improvement activities by supervisors. Supervisors subsequently played a leading role in Kaizen activities at Toyota, whereas the role of supervisors in Kaizen was very limited at Ford after it established the mass production system. According to Nemoto (1992), Kaizen activity was formally incorporated into responsibility of shop floor supervisors (shoku-cho and kumi-cho) around 1955[86] .

The introduction of TWI for training of shop-floor supervisors may be closely related to the replacement of traditional foremen-craftsmen with modern supervisors in the early post-war era. Facing the shortage of talent for the new job, Ohno had to convert plant staff and engineers to the supervising jobs as a temporary measure. Toyota thus needed a formal training program for the new supervising job. It is likely that TWI was used for filling the gap of the craft-style foremen.

<u>From SQC to TQC</u>: The Automobile Industry did not play an active role when the Total Quality Control concept emerged in Japan in the 1950s. After both Nissan and Toyota dispatched their staff to the seminars of the US-born Statistical Quality Control (SQC) in 1949 and adopted it, both companies were emphasizing capability of inspection, but TQC concept was not prevalent[87]. In the late 1950s, Nissan moved one step ahead of Toyota and won

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[84] Toyota Motor Corporation (1978), pp. 181.

[85] See Robinson and Schroeder (1993) for detailed illustration of TWI.

[86] See Nemoto (1992).

[87] See, for example, Udagawa (1993) and Nonaka (1994).

Deming Prize in 1960. Nissan outperformed Toyota in domestic car market share and exports in the early 1960s. Toyota's low quality level was blamed by APA of U.S. military force. Import liberalization was forthcoming.

Against this background, Toyota introduced Total Quality Control (TQC) in 1961. Unlike JIT, TQC was introduced to the company in a top-down manner, and its diffusion was quick. Eiji Toyota explained the objectives of TQC as follows:

> Improvements in quality did not progress as fast as improvements in efficiency. Also, the problems of newly recruited workers, insufficient education programs, lack of managers' capabilities and skills, and poor coordination across functions surfaced. At the same time, competition of quality against the rival auto makers intensified[88] .

In 1963, model changeover of Corona (a small passenger car) was chosen as a company-wide theme for TQC. In 1965, Toyota received Deming Implementation Prize.

Unlike Nissan, whose top managers tended to regard TQC as a campaign for winning the prize, Toyota's managers were more committed to continuation of TQC. In 1965, Toyota created procurement administration department (kobai kanri bu) and started to diffuse both JIT and TQC to the suppliers[89]. Toyota won Japan Quality Control Award in 1970, when Toyota had outperformed Nissan in the rapidly-growing domestic market.

4.5 Building Suppliers' Capabilities

In the early 1950s, the Japanese automobile supplier system was very different from what we see today. Many of the basic patterns of so called Japanese supplier system, including long-terms relations, multi-layer hierarchies, "Alps" structure, Just-in-Time delivery, subassembly of components by first-ties suppliers, involvement of first tier suppliers in product development, competition by long-term capabilities, close operational control and assistance by the auto makers, etc., were gradually formed in the 1950s to 1970s[90] . The high growth of production volume and proliferation of models during the 1960s facilitated the formation of multi-layer hierarchy of control and assistance.

<u>Technical Assistance to Suppliers</u>: According to Wada (1991), a management diagnosis for Toyota and its twenty one suppliers (keiretsu shindan), conducted by staff of

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[88] Toyota Motor Corporation (1978), pp. 251.

[89] Masao Nemoto, the first head of Purchasing Administration Department, as well as Taiichi Ohno, played a central role in this diffusion process.

[90] See Nishiguchi (1989, 1993), Wada (1991), Oshima, ed. (1987), Sato, ed. (1980), and so on.

Aichi prefecture in the early 1950s, pointed out that Toyota had not provided enough technical supports to its keiretsu suppliers, and that its purchasing department needed more people. Although Toyota initially took this diagnosis rather reluctantly, it quickly responded to this warning and strengthened its technical assistance, inspection and data collection for its suppliers. On the supplier side, kyoryoku-kai started to hold a series of joint seminars and plant visits. By the mid 1960s, activities of Kyoho-kai had been coordinated with Toyota's annual management objectives, and Kanban had been introduced to some of the suppliers.

Evolution of the Specialist Suppliers: In the 1950s, the main focus of auto makers' purchasing policy was to acquire additional production capacity from the suppliers in response to the production volume increase. During the 1960s, however, the auto makers made significant efforts to grow specialist parts makers within their supplier network, each of which specialize in a particular component in term of it capability of technology, manufacturing and subassembly. In stead of purchasing piece parts from many smaller suppliers, the assemblers bought subassembled functional parts from a smaller number of specialist suppliers. While the selection process of the first-tier suppliers went on, multi-layer hierarchies of supplier were gradually developed. The assembler encouraged the specialist suppliers to sell components to other assemblers to pursue economy of scale.

Although this pattern of division of labor between assemblers and suppliers turned out to contribute to competitive advantage of the Japanese auto makers in the 1980s, the initial motivation of the assemblers toward this direction might have been the pressures of subcontracting out a larger fraction of production-engineering activities to suppliers dung the high growth era of the 1960s.

Black Box Parts: Black box parts system refers to a certain pattern of transactions in which a parts supplier conducts detailed engineering of a component that it makes for an automobile maker based on the latter's specification requirements and basic designs[91].

One of the origin of the black box parts practice is likely to be transfer from either locomotive or aircraft industry of the prewar era, since the earliest adopter of this practice included prominent suppliers in these industries.

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[91] For further details, see Fujimoto (1994a).

The American auto industry was not the source of this practice, however. Historical evidences make us infer that the transactions between Toyota and Nippondenso in 1949 was probably another origin of the black box parts practice. Historical imperatives, or technological constraints, seem to have played an important role here: First, before the war, Toyota could not find decent electric parts suppliers in Japan, so it was almost forced to design and make such parts in-house; Second, after the war, Toyota had to separate the electric parts factory for its own survival; Third, when Nippondenso was created in 1949 as a result of the separation, Toyota found that it had to rely on engineering capability of Nippondenso, as virtually all the electric engineers had moved to the separated company. In this way, the historical imperative that Toyota lacked technological capability for electric parts appears to force Toyota to apply the approved drawing (i.e. black box parts) system to its transactions with Nippondenso from the beginning.

The diffusion of the black box practice peaked much later: in the late 1960s, which coincides with the period of rapid model proliferation during the motorization period. This fact makes one infer that another historical imperative of high growth with limited resource inputs in the product engineering area of the auto companies created constant pressures to subcontract detailed component engineering wherever possible: the diffusion of the black box practice.

From the suppliers point of view, the black box arrangement meant a great opportunity to develop its own design capability, build up a technological entry barrier against the auto makers' efforts to make the parts in-house, and survive as a first-tier parts supplier. Competitive pressures from the rival suppliers also accelerated their efforts to build up design and engineering capability in order to match up with their competitors' efforts.

It should be noted, however, that the content of the black box parts practice was in fact very different between Toyota and Nissan, that the former exploited potential benefits of the practice in terms of cost reduction much more effectively, and that Nissan adopted Toyota's system during the 1980s after it realized the difference between the two companies[92]. This indicates that, although both companies had to responded to similar

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[92] See Fujimoto (1994a).

historical pressures from the environment toward black box parts, their evolutionary capabilities were significantly different, which created a significant differences in effectiveness of the black box parts system at the two companies.

4.6 Evolution of Heavy-Weight Product Manager

Transfer from the Aircraft Industry: Heavy-weight product manager system is one of the core capability of effective product development organization. Historical evidences indicate that the origin of this powerful project leader system is the "chief designer" organization in the prewar aircraft industry (Hasegawa, 1993; Maema, 1993). Because of the nature of the aircraft, which required a high system integrity, its development project inherently needed strong product manager, an aircraft engineer, who played a role of strong system concept creator and project coordinator at the same time. When the Japanese aircraft industry disappeared after the war, a large number of talented aircraft engineers were forced to find jobs in other industries, including the automobiles. The massive inflow of the aircraft engineers dramatically enhanced the technological capability of the post-war auto makers.

Toyota as Pioneer: Although all of the post-war auto makers benefited from the technological capabilities that the ex-aircraft engineers brought with them, including body structural analysis and aerodynamics, Toyota was virtually the only company that directly adopted the institutional aspect of the aircraft development system: the heavy-weight product managers (or what Toyota called "shusa") system. Tatsuo Hasegawa, once a young chief designer of Tachikawa Aircraft, recalls that he had a clear intention to introduce the chief designers system to Toyota when he came to Toyota[93]. Toyota formally adopted the product manager system in the 1950s, far ahead of the other Japanese auto makers. Hasegawa lead some projects as product manager during the 1960s, including the first generation of Corolla.

Diffusion Process: Diffusion of the heavy-weight organization occurred much later, though. Honda introduced a strong project leader system in the early 1970s after Soichiro Honda, the one-man chief engineer, retired. All the other auto firms moved to heavy-weight

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[93] Hasegawa (1993). See, also, Maema (1993).

product manager organizations between the late 1970s and the 1980s. The sizable time lag between the origin of the heavy-weight system (1950s) and its diffusion (1970s and 1980s) indicates that the real competitive advantage of the system became obvious when the market started to emphasize "product integrity," or coherence of the total vehicle design[94]. During the 1980s and the early 1990s, the heavy-weight product manager system was adopted by many of the Western auto makers.

4.7 System Emergence and Evolutionary Capabilities: A Summary

Summary of Historical Analysis: The above historical analysis of the successful development-production systems in the post-war Japan seems to be consistent with the predictions mentioned at the beginning of section 4. That is:

- Many of the capabilities were gradually acquired by the competing firms throughout the post-war period, particularly between the 1950s and 70s, although some of the practices are dated back to the pre-war era. There was apparently *no grand strategies* on the sequence of capability acquisition. It was rather a long-term *evolutionary* process.
- Some aspects of the capabilities of the effective development-production systems were found at the Japanese makers in general. There were obviously region-specific factors (i.e. *Japan effect*) in the evolutionary process.
- Some other aspects of the capabilities were found only in certain manufacturers known for its high competitive performance, typically Toyota. Thus, inter-firm differences in capability building was observed even within the group of Japanese auto makers. In other words, firm-specific factors (i.e., *Toyota effect*) coexisted with the region-specific patterns during the 1980s.
- Still other aspects of the system were generic, or common with automobile mass producers worldwide, in that they all introduced some elements the standard Ford system directly or indirectly (i.e., *Ford Effect*). It is a myth that Toyota system is a totally unique antithesis of Ford system. It was rather a product of continuous *hybridization.*

To sum up, the historical findings were generally consistent with the prediction mentioned earlier that the Toyota style system we have observed during the 1980s was a combination of (1) universally adopted practices (Ford Effect), (2) region-specific capabilities (Japan effect), and (3) firm-specific capabilities (Toyota effect).

Also, the foregoing cases of system emergence and capability building seems to indicate that the development-production capability of the effective Japanese auto makers

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[94] As for the concept of product integrity, see Clark and Fujimoto (1990, 1991).

gradually emerged as a result of complex interactions of entrepreneurial visions, historical imperatives, inter-firm and inter-industrial transfer of resources and practices, pure chances, as well as the firms' own evolutionary capability (figure 6). Table 4 indicates the complexity of the dynamics in the selected cases.

Let us now try to classify theses explanations roughly into universal, region-specific, and firm-specific effects in the capability building processes:

(1) Factors Affecting Universally Adopted Capabilities

- Perceived pressures of international competition: Toyota's capability building was consistently motivated, since the 1930s, by perceived competitive pressures from the U.S. mass producers, particularly Ford. Even with strongly protected domestic market between the 1930s and 50s, Toyota's consciousness of the imaginary competitive pressures persisted.

- Direct and indirect adoption of Ford system: Motivated partly by the above consciousness of international competition, Toyota adopted many elements of the Ford system and American mass production system mostly indirectly, including moving conveyers, transfer machines, product and component designs, Taylor system, supervisor training program, and statistical quality control. Pure dichotomy between Ford system and the Toyota system as the post-Ford paradigm is therefore misleading.

(2) Factors Affecting Region-specific Capabilities

- Benefits of Historical Imperatives by Forced Growth: Some of region-specific imperatives that all the Japanese firms faced during the post-war era almost "forced" them to make certain responses, some of which turned out to be contributing to competitive advantages of those firms. Many of such responses were not recognized as competitive weapons when the forms first adopted them. For example, *the imperative of forced growth* , both in production and product development, with limited supply of production inputs and the fear of labor conflicts, turned out to facilitate capability building for productivity improvements through avoidance of intra-firm overspecialization, division of labor between assemblers and suppliers, as well as avoidance of excessive use of high-tech equipment on the shop floor.

- Benefits of Historical Imperatives by Forced Flexibility: Likewise, the *imperative of forced flexibility* in the fragmented market also benefited the Japanese firms. This is partly because of the region-specific patterns of industrial growth: a rapid production growth accompanied by rapid product proliferation. The flexibility that the firms acquired tended to be recognized as necessary evil to cope with the fragmented market, rather than a measure for international competition, when the capabilities were first built. It should be also noted that, as is obvious from the comparison of the Japanese and U.K. production systems, that the fragmented markets do not automatically create effective flexibility.

- Benefits of Historical Imperatives by Lack of Technology: While excessive use of high-tech automation equipment often became even obstacles against productivity improvement, the effective Japanese makers apparently avoided such problems. This may be partly because they consciously rejected the temptation for over-specialization, but it also seems to be partly because high technology was not there in the first place. To the extent that this was caused by certain region-specific technology gaps, the lack of technology may bring about unintended competitive benefits to firms of a region.

Table 4 Summary of Evolution of Selected Production-Development Capabilities

	Just-in-Time	Multi Tasking with Product-Focus Layout	Jidoka and Flexible Equipment	Kaizen and TQC	Black Box Parts	Heavy-weight Product Manager
competitive effect (rationality)	creating pressure for productivity improvement throughput time inventory cost	productivity improvement	pressures for quality improvement flexibility	quality improvement productivity improvement	cost reduction by manufacturability development lead time and productivity	high product integrity development lead time and productivity
entrepreneurial vision	Kiichiro Toyoda, 1930s ("just in time" slogan) Taiichi Ohno, 1940s -50s (system building)	Kiichiro Toyoda, 1945 (a vision of rapid productivity catch-up without economy of scale)	Kiichiro Toyoda, 1931 (a vision of high productivity with small volume production)			
transfer from other industry	textile (bench marking of Nichibo) prewar aircraft production	textile: multi-machine operation in spinning (through Ohno)	textile: Sakichi Toyoda's automatic loom	TQC was established in other industries (e.g. process industry)	prewar locomotive or aircraft parts supplier	prewar aircraft industry (chief designer system) forced transfer (collapse of aircraft industry)
transfer from Ford system	the synchronization idea from Ford (invisible conveyer line) Kanban as "incomplete synchronization"	productivity bench marking with Ford modified Taylorism	adoption of Detroit-type automation where feasible U-shape layout as "incomplete transfer machine"	suggestion system from Ford Training Within Industry Statistical Quality Control		
imperative of forced growth with resource shortage		limit of permanent work force after the 1950 strikes "forced" productivity increase in the 1960s	shortage of investment fund: low cost automation had to be pursued	shortage of supervisors replacing craftsmen-foremen = needs for TWI	high production growth and model proliferation created pressures for subcontracting subassembly and design	
imperative of forced flexibility with small & fragmented market			"forced " flexibility of equipment due to small volume		product proliferation of the 1960s created pressures for subcontracting out design jobs	product proliferation with limited engineering resource created pressure for compact projects
imperative of shortage of technology	lack of computer production control technology in the 1950s and 60s		lack of adaptive control automation: Jidoka needs human intervention		lack of electric parts technology at Toyota in 1949 (separation of Nippondenso)	
ex-post capability of the firm		flexible task assignment and flexible revision of work standards to better exploit opportunities of productivity increase		Toyota maintained momentum for TQC by creating organizations for diffusing it to suppliers	Toyota institutionalized a version of black box parts system that could better exploit competitive advantages	Only Toyota adopted heavy weight product manager system from the aircraft industry as early as 1950s

- Region-Specific Knowledge Transfer: Region-specific patterns of capabilities may also emerge when intra-regional knowledge transfers are more dense and frequent than inter-regional ones. The suppliers network shared by the Japanese firms was one of such transfer instruments. Intense competition between domestic makers during the 1960s and 70s may have also facilitated their efforts for learning from the domestic competitors.

- Benefits of Unintended Transfer: As in the case of engineers from the prewar aircraft industry, the "push" type knowledge transfer, which the receivers did not intend o make, brought about rapid increase in automobile technologies and product development systems of the post-war automobile industry in Japan.

- Benefit of Incomplete Knowledge Transfer: Although the Japanese auto firms tried to adopt many of the practices and techniques from the US mass producers (i.e., Ford system), some of them were incomplete due to the historical imperatives mentioned above and lack of the firms' absorption capacities. I this sense, Kanban system may be regarded as incomplete version of the conveyer system, U-shape machine layout as incomplete transfer machine, and Jidoka as incomplete adaptive automation. The very incompleteness of the transfer may have facilitated its subsequent diffusion to the entire system. For example, the case of Kanban system may be regarded as *complete diffusion of incomplete synchronization technology*.

(3) Factors Affecting Firm-specific Capabilities

- Benefits of Self-fulfilling Visions: Form-specific entrepreneurial visions sometimes played an important role in building distinctive development-production capability. This was particularly the case when an apparently unrealistic visions that go against common sense triggered self-fulfilling efforts for achieving the bold objectives. Kiichiro Toyoda in the 1930s and 40s played a pivotal role in this sense in advocating cost reduction without economy of scale, catch-up with Ford, and Just-in-Time philosophy. Nissan of those days did not have his counterpart.

- Linkage to Other Industries: Some of the linkages to other industries, which were technologically advanced in the past, may be firm-specific. For example, Toyota's inherent connection with the textile industry may have facilitated knowledge transfer from it (particularly through Taiichi Ohno) created its competitive advantages in production control techniques .

- Advantages by Post-trial Capability: Even when no firms recognized potential competitive advantage of the new system when they first tried it, some firms could still create firm-specific competitive advantages by exercising *post-trial capability:* by recognizing the potential competitive advantage of the new system, modifying it to exploit the potentials, institutionalizing it, and retaining it until the advantages are realized. For example, even though all the Japanese auto makers faced similar environmental pressures for adopting black box parts system in the 1960s, only Toyota appears to have created a system that could fully exploit potential advantages of this practice. Although all the Japanese auto makers accepted aircraft engineers after the war, Toyota was the only company that institutionalized heavy weight product manager system that was prevalent in the aircraft industry. Thus, even when all the Japanese firms faced certain historical imperatives that facilitated new practices, only a part of them may have materialized this potential luck by employing firm-specific evolutionary capability.

In summary, a combination of the logic of system emergence, including historical imperatives, knowledge transfers, entrepreneurial visions and post-trial capabilities, seems to be able to explain why firm-specific, region-specific and universally adopted capabilities coexisted, as well as how they emerged, in the effective product development and production systems in the Japanese auto industry of the 1980s.

4.8 A Conceptual Implication: Dual Layer Problem Solving

Dual Layer Problem Solving The present paper has so far argued that the development-production systems of successful Japanese auto makers of the 1980s has a certain competitive rationality as a total system (section 3). At the same time, historical analyses of the paper (section 4) indicated that the system of the capabilities, even though they were ex-post rational in terms of competitiveness, were not created all a once by deliberate and strategic decisions, but were developed as a result of cumulative and evolutionary processes. Individual elements of the development-production capability tended to be tried, selected and retained in the system at different timing and for different reasons, while the total system gradually and steadily improved its total competitive capability until the 1980s. The logic of the origins, diffusion, and stability (i.e., competitive rationality) of a new system were sometimes all different, as in the case of black box parts. The capabilities were often adopted unintentionally as the firms were forced to respond to certain historical imperatives, or at least without knowing the potential competitive benefits. Solutions often existed prior to the competitive problems.

A standard model of problem solving cycles that flows smoothly from goal setting to problem recognition, alternative search, alternative evaluation, selection, and retention of the solution does not seem to explain this phenomenon well[95]. At the same time, however, we have to keep in mind that the process eventually created a rational system in terms of competitive advantages. The process was neither totally chaotic nor irrational.

For a conceptual model that may help us understand this evolutionary process, the present paper tentatively proposes a *dual level problem solving* framework, that consists of two levels of problem solving or learning mechanisms (figure 9). The lower level mechanism generates miscellaneous solutions for various purposes, while the upper level mechanism absorbs the solutions and convent them to development-production capabilities.

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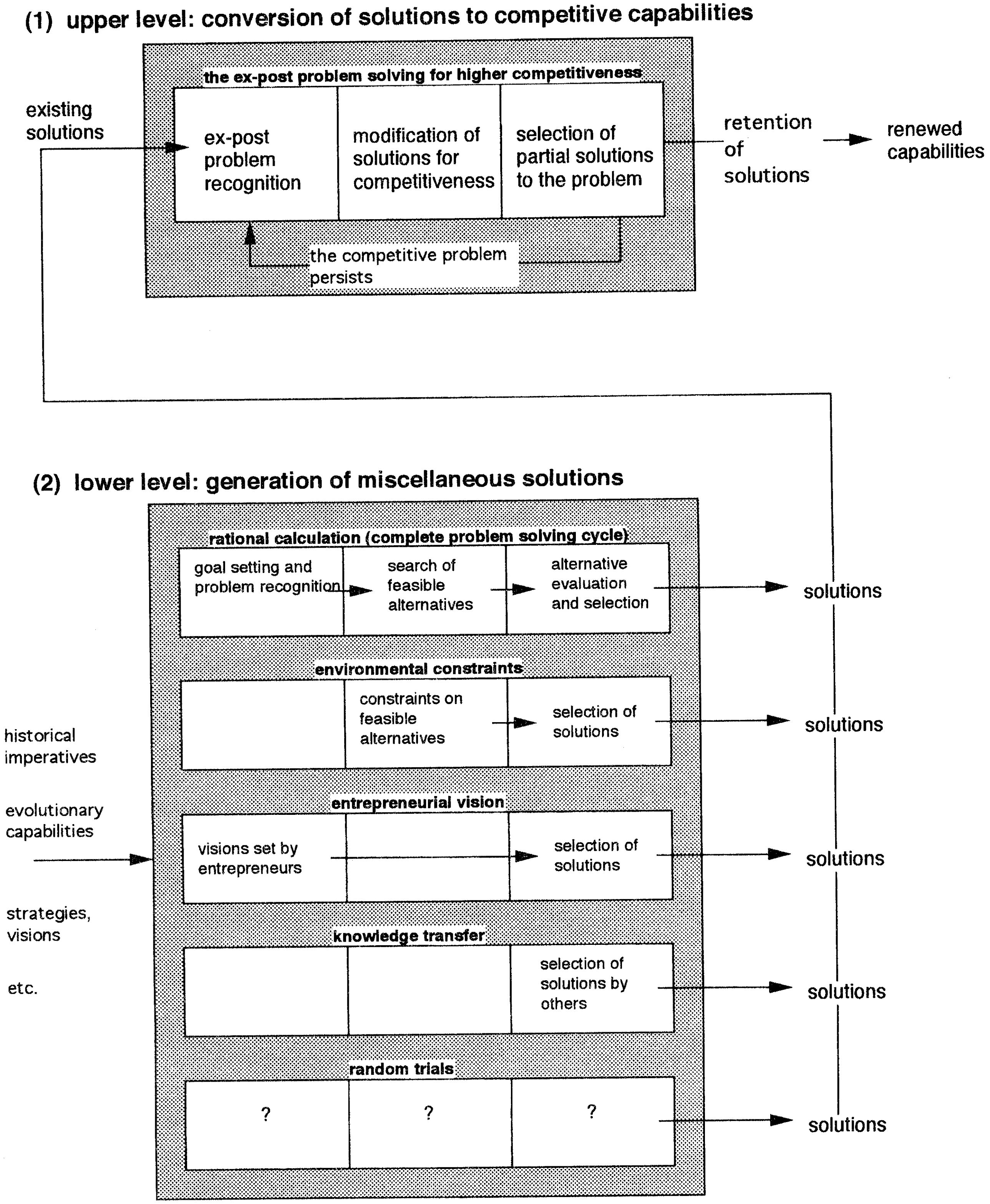
[95] See Simon (1945, 1961), March and Simon (1958).

Figure 9 Dual Layer Problem Solving : A Simplified Framework



Lower Layer: Generation of Solutions: As figure 9 indicates, the lower level consists of various types of complete and incomplete problem solving cycles that generate solutions (patterns of activities that the firm selects) of various kinds. They corresponds to the types of system emergence shown in figure 6. *Rational calculation* represents complete problem solving cycles with explicit goal setting, problem recognition, deliberate examinations of constraints on the alternatives, evaluation and selection of the feasible alternatives. *Entrepreneurial visions*, on the other hand, tend to lack deliberate assessment of constraint: the solutions are chosen predominantly by goals (i.e., visions) of the entrepreneurs regardless of their feasibility. In the case of environmental constraints, by contrast, recognition of constraints, rather than goal setting, drives selection of solutions. In *knowledge transfer*, solutions that other organizations selected are often replicated without deliberate analysis. In any case, miscellaneous solutions are created with or without problems. The solutions may not be solutions to competitive problems, but to some other non-competitive problems.

Upper Layer: Conversions of Solutions to Capabilities: The upper level of figure 9, on the other hand, is oriented to the problem of competitiveness and its improvements. This mechanism is a kind of problem solving or learning process in a broad sense, but it differs from regular problem solving cycles in that the problem is never fully solved but persists in the long run, and the solutions are only partial solutions. After all, the process of competition is endless, and so is the problem of maintaining and enhancing the firms' competitiveness. In March-Olsen's term, the mechanism may resemble a huge garbage can which is never cleared while absorbing miscellaneous solutions from the lower level[96]. The garbage can takes in the miscellaneous existing solutions, created originally for coping with other problems, as raw materials, gives them a competitive focus, and converts them to a system of competitive capabilities. The system never completely solve the problem of winning the competition, though. Various competitive and non-competitive solutions arrive at this conversion process one after another, trigger ex-post problem recognition, and are retained for subsequent processing and modified to exploit their potentials as competitive weapons.

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[96] See March and Olsen (1976) and March (1988).

Thus, the system evolves for higher competitiveness in the long run, but the problem of winning the competition itself never goes away.

The firm-specific ex-post capability of capability building, discussed earlier in this paper, is essentially a capability of handling this upper level process. It is a capability of effectively converting miscellaneous existing solutions to a set of distinctive development-production capabilities. Such evolutionary capability would include the firms' ability of ex-post problem recognition, effective routinization of potentially competitive solutions, modification to exploit their potentials, and hybridization with the existing system of capabilities. For example, many of Toyota's distinctive evolutionary paths, illustrated in this section, seems to be based on its ability of effectively converting existing solutions to a distinctive system of capabilities. Although further analysis is needed to elaborate this preliminary idea, the dual layer problem solving framework may help us understand the evolutionary process of the competitive production systems, as well as the role of firm-specific dynamic capabilities in it.

5 Conclusion

The present paper explored the possibility of applying resource-capability view of the firm to the case of production and product development systems in a single business situation. The argument of the paper may be summarized as follows:

- *Information System Approach*: The resource-capability theory of the firm may be reinterpreted from an information point of view for its application to detailed analyses of product development and production systems. Firm, resource, activity, product, consumption, product development, production, competitiveness, and capability can be consistently described as information assets and their creation and transmission.

- *Total System perspective:* Production and product development resources, activities and capabilities can be consistently analyzed as an integrated total system from the information creation and transmission point of view. Both aspects, knowledge creation and information transmission, are crucial for understanding the development-production capability of a manufacturing firm.

- *Three Levels of Capabilities:* A firm's capabilities in product development and production need to be analyzed at three level: static, improvement, and evolutionary.

- *Production Capability Reinterpreted:* Production capability of the effective Japanese auto makers of the 1980s can be characterized as dense, regular and accurate transmission of value-carrying information between flexible information assets. The system for higher productivity and shorter throughput time is designed from the information receiver side, while the system for higher conformance quality is designed from the information source side.

- *Product Development Capability Reinterpreted*: Product development capability of the effective Japanese auto makers can be also illustrated as dense information processing with frequent and high band-width transmission of information that is created and elaborated incrementally by short problem solving cycles.

- *Improvement Capability:* There are a variety of mechanisms that facilitate repetitive problem finding, problem solving and solution retention for consistent and rapid improvements for competitive performance. The core part of the effective Japanese auto makers (e.g., Toyota Production System, JIT, and TQC) is this organizational learning process.

- *Evolutionary Capability:* The system emergence process of the effective development-production capabilities is much more complex than straight-forward rational behaviors. While the capabilities as a total system may be ex-post rational, each element of the system may have emerged for other reasons than competitive advantages, such as certain historical imperatives and forced technology transfers. At the same time, certain firm-specific capabilities, such as entrepreneurial visions and ex-post capabilities of converting unintended trials to competitive capabilities, may also play important roles in the emergence of competitive development-production systems. This complex process may explain why significant inter-regional and inter-firm differences in performance coexisted at the same time.

- *Dual Layer Problem Solving:* The process of capability building and system evolution may be partly explained by a modified problem solving or learning model that consists of a mechanism of solution generation and that of solution conversion to competitive capabilities that interact with each other. The process does not assume complete problem solving cycles, but it may help us understand why an ex-post rational system evolves without deliberate strategic decision making of the firm.

I this way, the resource-capability view of the firm may be applied effectively to the case of development-production systems in a single business situation, where both inter-regional and inter-firm differences in competitive performance are consistently observed. Such analyses, in-turn, may serve as building blocks for higher levels of strategic analyses at multi-industry, multi-divisional manufacturing firms.

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