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System Emergence and Organizational Capability:

Analyzing Operation-based Competence Using an Evolutionary Framework

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Abstract

This paper explores concepts and frameworks for analyzing the formation of a firm's complex operation-based competency, such as that of the Toyota Motor Corporation in manufacturing. For this purpose, this paper proposes to link a resource-capability view of a firm with its evolutionary framework, presenting a dynamic perspective that separately explains an observed system's survival (i.e., its functional logic) and its formation (i.e., its genetic logic). In this way, two main concepts are derived: "multi-path system emergence" for analyzing the complex variation of operational system changes, and "evolutionary learning capability" for explaining why certain firms can create complex operation-based competency faster and better than their competitors. This paper applies these frameworks in a historical analysis of operation-based routines at Toyota.

Key Words: evolution, operation-based competency, Toyota, system emergence, organizational routine, organizational capability, dynamic capability, organizational learning, emergent strategy

Introduction

Purpose of the Paper

A firm's resource and organizational capability in operations such as production, product development and procurement have been regarded as one of major sources of its competitive advantage and above-normal profit. There have been a number of research studies analyzing structures and functions of such operation-based competency such as lean production system and total quality management (Womack et al., 1990; Clark and Fujimoto, 1991). Still yet, academic research on how a firm develops such competency better than its rivals have so far been rather underdeveloped.

By "complex operation-based competency" I mean a firm's specific system of many interrelated organizational routines (Nelson and Winter, 1982) in value-creating operations (e.g., production and product development) that results in consistently better productive performance (e.g., productivity and lead-time) than its competitors. Examples of such competency include that of Ford and Toyota in their respective production systems in the twentieth century. Existing researches have revealed that such competency tends to be developed through a long-term cumulative process as opposed to one-time project or investment (Hounschell, 1984; Cusumano, 1985; Fujimoto, 1999). They have also described the formation of operation-based competency as a complex interplay of plans and chances, visions and imperatives, creations and imitations, and trial and errors. If this is the nature of the complex operation-based competency in question, what kind of conceptual framework should we adopt for better understanding of such phenomena?

Existing literature in management studies, however, tended not to explicitly answer this particular research question. For example, resource-based view of strategic management explains how a firm's resource or capability creates above-normal profit, but it seldom explains why such competence emerged at certain firms but not at the others. Researches on dynamic capability try to answer this question, but it has not covered long-term development of a complex operation-based competence. Theory of organizational learning analyzes processes through which a firm changes its organizational routines, but it does not deal with long-range history of many routine changes within one firm. Operations management literature explains routines regarding manufacturing and continuous improvement, but historical emergence of such routines themselves is beyond its research scope. Process innovation has been a popular topic in technology management literature, but its research agenda tended to be limited to either each individual innovation or a series of innovations at the industry level. Thus, a long-range formation of operation-based competency that happens within a single firm, despite its importance in industrial competition, has so far been a rather uncultivated field in management studies.

Against this background, the purpose of this paper is to explore a conceptual framework that may explain how a firm gains competitive advantage through developing and maintaining complex operation-based competency. The framework that I propose is an application of evolutionary theory of social systems to the issue of intra-firm development of a complex operation-based competency. I chose this evolutionary framework based on my view that it can explain a dynamic process of a complex system formation most consistently. More specifically, the present paper makes two arguments for this purpose. First, it proposes the concept of *multi-path system emergence* as a schema that may explain the change process of a complex operation-based competency. Second, the paper argues that a firm gaining operation-based competitive advantage needs three layers of organizational capabilities that include *evolutionary learning capability.* In the empirical part of the paper, I will apply the above-mentioned framework to the case of Toyota-style manufacturing system in the second half of the twentieth century.

Overall, this paper tries to reinterpret the evolutionary theories in social science in the context of industrial competition through organizational capability-building. Generally speaking, an artificial system, which looks as if it were deliberately designed as a rational one in terms of competitiveness or survival, may have been formed through a complex dynamic process which itself cannot be reduced to an ex-ante rational planning alone. When we observe an ex-post rational object that may not have been formed in an ex-ante rational way, a certain *evolutionary framework* can often be applied effectively to such a case. By evolutionary framework I mean a dynamic perspective that separately explains an observed system's survival (i.e., the functional logic) and its formation (i.e., the genetic logic). For example, a prevalent neo-Darwinian (or synthetic) theory of biological evolution assumes natural selection for explaining a living system's survival, and random variation for its origin. Indeed, a number of past researchers applied some sort of evolutionary approaches to dynamic analyses of biological, social or economic systems of this kind.

Thus, the present paper aims to propose an evolutionary framework that may be applicable to an artificial system that I believe is ex-post rational: the operation-based competency such as that of Toyota Motor Corporation. Although my analysis here is by no means a direct application of neo-Darwinism or biological models, it is still evolutionary in that I separate the functional logic and the genetic logic on the manufacturing system at Toyota.

In the next section, an evolutionary framework that may be applicable to certain types of process innovations is presented and compared with existing evolutionary theories in biology and social science. In the third section, the concepts of "multi-path system emergence" and "evolutionary learning capability" are illustrated in more details. In the fourth section, these concepts are operationally re-defined and applied to the case of Toyota-style manufacturing system. Based on this historical-empirical analysis, it is argued that the ultimate core competence of this high-performing manufacturer in the last half of the twentieth century is likely to be its evolutionary learning capability.

An Evolutionary Framework for Sosial Systems

Since C. Darwin's work on living systems, various types of evolutionary frameworks have been applied to the cases of social, economic and managerial systems. The notion of evolution, however, has been quite equivocal, which often created misunderstanding among researchers of different fields. In order to avoid conceptual confusions, I distinguish two levels of an evolutionary framework: a general scheme and a specific scheme. The present evolutionary approach shares its basic logical structure with many other evolutionary theories of biological and social systems at the first level, while it is more or less specific to the present analytical purpose: the empirical research of manufacturing systems and process innovations at the second level.

General Scheme of Evolutionary Framework

Let's start from the generic level. By evolutionary framework at this level, I do not mean any specific theories of biological or social evolution, but a general logical scheme that such theories may share. It shows what I think is a common denominator for any models or theories to be called "evolutionary." At this level, the present framework shares basic logical patterns with contemporary synthetic (neo-Darwinian) theory of biological evolution, as well as evolutionary theory of the firm, technologies, organizations and strategies. At this level, we may call a framework "evolutionary" when the conditions mentioned below apply.

(i) Variety and Stability: The framework's main purpose is to explain why we observe a certain variety or difference of stable patterns (e.g., species) in the objects concerned (e.g., living systems)

(ii) Ex-post Rationality: The objects observed behave so functionally that they look as if someone had purposefully designed them for survival, regardless of whether such purposive motivation actually existed beforehand.

(iii) History: The present pattern of the objects is conjectured to have been formed historically through a certain path over a long period.

(iv) Genetic and Functional Logic: The framework prepares three complementary explanations for a given dynamic phenomenon: the logic for system *variation* (generation of a variety of patterns), *selection* (elimination of low-performing patterns), and *retention* (preservation of the remaining patterns). In other words, the evolutionary perspective provides *genetic* and *functional* explanations separately to the same object: The former shows how it evolved into what we see now, whereas the latter demonstrates how it behaves effectively for higher performance or survival rate.

(v) Anti-Teleology: Because of the above logical separation, this framework does not have to depend on ex-ante rational foresight of omnipotent decision makers for explaining the formation of the ex-post rational system. In other words, the evolutionary logic denies depending totally upon teleology.

The evolutionary framework of this paper shares the above logical scheme with many of other evolutionary theories for biological and social systems.

Note, again, that the generic evolutionary framework separates genetic analysis (i.e., how the system was created and has changed to yield its present form) and functional analysis (i.e., how a system's structure has contributed to its survival and growth), which is the heart of evolutionary thinking.

Specific Scheme of Evolutionary Framework

At the second level, the evolutionary framework is applied specifically to the case of a complex operation-based competency within a single manufacturing firm like Toyota. In other words, the present framework deals with intra-firm evolution of organizational routines.

Note here that, considering the nature of this paper's theme (i.e., long-term changes in operational routines within a single surviving company), I assume that individual firms (e.g., Toyota) can adapt their internal system to the environments and thereby survive at the firm level. As Barnett and Burgelman (1996) point out, one may also conceive of another type of evolutionary models, in which individual firms are unable to adapt its internal structures to the selection environment, and that those firms with ineffective routines are simply weeded out; It is the population of firms as a whole that adapt. (e.g., organizational ecology by Hannan and Freeman, 1989). This paper does not adopt such neo-Darwinian (or population ecology) versions of evolutionary models, though. The present paper instead assumes that individual firms may internally select their manufacturing routines through what Robert Burgelman would call an "intraorganizational ecological process" (Burgelman, 1994), before being selected by external ecological process.

The specific scheme for cumulative operational capability-building can be summarized as follows (See Fujimoto, 1999, for further details):

(i) Retention: Based on the author's view that production is transmission of product design information from the process to the product (Fujimoto, 1999), the present framework assumes that what is retained in a manufacturing system is a stable pattern of *information assets and flows* that collectively influence manufacturing performance. This informational pattern, or "gene" of the manufacturing system, may also be called *routines, productive resources,* or routinized capabilities. In other words, the present study re-interprets manufacturing routines as a detailed pattern of stocks and flows of value-carrying design information.

(ii) Variation: The present framework treats changes in manufacturing routines as an *multi-path system emergence,* a complex and irregular combination of rational plans, entrepreneurial visions, historical imperatives, pure chance, and so on. In this sense, the present evolutionary model is not Neo-Darwinian — the latter only assumes pure randomness as an ultimate source of genetic variation, denying the possibility of feedback from the environment to the genes (routines). The present model is rather Lamarckian in that it recognizes individual firm's efforts to adapt its routines to the environment, although imperfectly.

The multi-path system emergence also differs from intentional "search" activities that some theories of evolutionary economics assume in that the former may include unintended trials. The system emergence is obviously akin to the concept of "emergent strategy"

(Mintzberg and Waters, 1985), but the former assumes a situation in which managers do not even know if a deliberate strategy works or emergent strategy is the case for the next system change.

(iii) Selection: The present framework assumes a *lenient selection mechanism.* As mentioned earlier, selection of routines may occur when firms with low-performing routines are immediately eliminated through market competition — a situation that so called organizational ecology may assume (Hannan and Freeman, 1989). This kind of "harsh" selection seldom happens in today's automobile industry, though[1]. For the present empirical analysis, a more realistic assumption is that firms with lower performance can still survive for some time, but that competitive pressures from "best practice" rivals tend to force such firms to select and change routines in the long run. In other words, the selection environment in this case is generous enough to allow automobile firms of different performance levels to survive. This study does not deal with direct selection of individual firms by the market environment, but analyzes selection of routines within a surviving firm (i.e., Toyota).

The market does function as a routine selection mechanism, but its impact is at most indirect in most cases of today's automobile firms (i.e., existing firms may switch routines in response to signals from the market). For long-term survival, what matters as a market signal is relative performance. The survivor's routines do not have to be optimal, but they need only to be better than competitors in the long run. To sum up, the selection process of the present framework is milder than what neo-Darwinian models of biology, population ecology of organizations or equilibrium models of microeconomics assume. Accordingly, the present framework regards relative manufacturing performance as a surrogate indicator of individual firms' "probability of future survival."

Comparison with Biological Neo-Darwinian Models

Overall, the evolutionary framework of the present paper is by no means new, but it is clearly different from some other interpretations of evolutionary models. For instance, whereas the present framework shares general logical scheme with today's synthetic theory of biological evolution, it is not a direct application of the biological model at the specific level (Table 1)

The prevalent paradigm in biology theorizes that variation (mutation as random changes of genetic information or DNA), selection (natural selection caused mostly by different propagation rates), and retention (reproduction of genetic DNA information in and across individuals) jointly create changes and diversification of genetic information, which then materialize in living systems through adaptation to changing environments.

For the purposes of microscopic empirical analyses of operational-technical systems, however, I do not follow the biological model at the level of specific scheme.

In the context of a social system, variation is explained not by the purely random process that Neo-Darwinism[2] may define in a biological system, but by a complex interaction of forces

1 Population ecology models may be applied more effectively in the case of earlier phase of automobile industrial evolution, in which many births and deaths of individual automobile manufacturers were observed. See, for example, Abernathy (1978) and Carroll et al. (1996) for the case of the US auto industry.

2 Note that I am using the term "Neo-Darwinism" broadly here as synonymous with so called the Modern Synthesis, the prevalent theory in biological evolution that includes revised Darwinism and Mendelian genetics.

Table 1 Comparison of Evolutionary Frameworks

	Framework of this book	Neo-Darwinian (synthetic) theory in biology
object	Manufacturing systems	Living systems
criteria of ex-post rationality	Relative manufacturing performance	Survival/reproduction
logic of retention	Object to be retained = manufacturing routines as informational patterns Routines are stored in the firm; It may be diffused across firms	Object to be retained = genes as information Genetic information is stored in the organism; It may be reproduced across generations
logic of variation	Emergent process changes routines Feedback from the environment may trigger routine changes (Lamarckian)	Random chance changes genetic information No feedback from the environment to gene
logic of selection	Long-term elimination of low-performing routines by either market or organization Rather "generous" selection environment is assumed Individual firms may select high-performing routines	Long-term elimination of low-performing genotypes by the environment Rather harsh selection environment is assumed Individual organism cannot select high-performing genes
separation of functional and genetic explanations	Genetic Explanations = Emergent processes result in changes in manufacturing routines Functional Explanations = Certain routines result in relatively high performance (static and improvement capability)	Genetic Explanations = Random variations of DNA result in variations of phenotypes. Functional Explanations = Certain phenotypes result in higher performance for survival in the environment (natural selection)
anti-teleology	Reject the idea that omnipotent decision-makers create the entire system through perfect foresight	Reject the idea that the omnipotent creator made all of the living system through predetermined plans

ranging from purely random to purely purposeful changes — a multi-path system emergence.

As for selection, as mentioned earlier, the present framework assumes a rather lenient selection environment, in that relatively weak organizations, with lower competitive performance, can still survive at least for a certain period. That way, it is possible to observe significant cross-organizational differences in performance for survival at a certain point in time (Clark and Fujimoto, 1991; Womack et al., 1990). Also, the framework may include certain internal selection mechanisms inside the organization that pre-screen the routines that have higher probabilities of survival in the external selection environment.

Finally, I only assume an incomplete mechanism for retention and duplication of organizational knowledge or information in a social system, unlike a relatively strict mechanism of gene or DNA duplication in the case of living systems. As anyone who has worked in a company knows, organizational routines and memories erode quickly. Also, they are often difficult to imitate by other organizations.

To sum up, the specific framework of this paper is indeed evolutionary, but it is not

Neo-Darwinian — the latter assumes random variation and harsh selection, while the former features emergent variation and lenient selection. And, quite obviously, I reject a crude "social Darwinism" that could be used to justify elimination of the "weak."

My framework may also disagree with some other specific interpretations of existing evolutionary models applied to social phenomena. For instance, I do not assume *progressivism,* or the doctrine that system evolution causes constant progression toward something inherently valuable or supreme. What the evolutionary process tends to bring about is not progress but simply adaptation to environmental requirements.

By proposing an evolutionary framework I don't also mean a *linear stage model.* Distinctive stages may be identified in ex-post historical analyses, but I don't assume such a pre-determined sequence of regular stages.

It does not assume that the system changes are always incremental (i.e., evolutionary rather than revolutionary), either, although I do emphasize cumulative aspects of system changes in the present empirical analysis. These are specific interpretations of the evolutionary perspective, but the current framework does not follow such specific versions of evolutionary theories.

Comparison with Existing Evolutionary Theories of Firms

Finally, let's discuss the relationship between the present evolutionary framework and existing evolutionary theories and models of business firms. Although this paper is, again, empirically motivated, it turned out that some existing theories fit better than others for explaining the data and materials: *evolutionary theories of the firm, resource-capability based approach,* and the concept of *emergent strategy formation.* The present paper adopted some (but not all) aspects of these theories. In this sense, much of my own analysis is based on the previous work of economists, historians, and business researchers, including Penrose, Nelson, Winter, Dosi, Rumelt, Teece, Chandler, and Mintzberg[3]

Both resource-capability based approaches to strategic management and evolutionary theories of the firm have attracted much attention among business academics and practitioners in recent years. Although they came from different academic traditions, these theories tended to share a common view of a firm, describing a company as a collection of firm-specific and difficult-to-imitate resources, organizational routines, capabilities, or competencies. Their proponents expect that such resources, especially when they represent a stable pattern of performance and associated behaviors, account for competitive differences between firms, as well as for the evolution of business enterprise systems[4]. The current framework also follow this routine-capability based view of manufacturing firms in a broad sense.

Nevertheless, at the level of specific scheme, the present evolutionary framework is not a direct application of these theories. Certain reinterpretation and modification is needed for detailed empirical analysis of automobile manufacturing competency such as that of Toyota.

While most of the existing resource-capability literature — found in the fields of strategic management, applied economics, and business history — analyzes the dynamics of the overall systems of multi-product firms, these studies have not been designed for detailed competitive

3 Penrose (1959); Nelson and Winter (1982); Dosi, (1982); Chandler (1990); Teece, Rumelt, Dosi, and Winter (1994).

4 For the concepts of resource, organizational routine, capability and competence, see, for example, Penrose (1959), Nelson and Winter (1982), Dosi (1982), Baryney(1984), Rumelt(1984, 1991), Wernerfelt (1984), Itami (1984), Chandler (1990, 1992) , Prahalad 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 organization and its strategies and technologies, see, also, Weick (1979), Nonaka (1985), Mintzberg (1987), and Burgelman (1994).

analyses of production and product development systems at a single plant or project level[5]. Previous research in technology and operations management has done a much better job of analyzing the specifics of manufacturing systems, but it tended to lack either the total system perspective or a long-range historical perspective[6].

It is also important to distinguish the evolutionary framework adopted for the present empirical analysis and the population ecology version of evolutionary models (e.g., Hannan and Freeman, 1989). The question here is whether firms can revise their routines for better chances of survival. As already mentioned, population ecology versions of the evolutionary theories hypothesize that firms are unable to adapt their routines in response to signals from the environment — a Neo-Darwinian interpretation of evolution. According to this assumption, existing routines may persist within a firm, or they may change purely randomly, but it is the external environment as a selection mechanism that creates a non-random distribution of high-performing routines in a given population of firms. Firms cannot select effective routines; the environment selects the firms. (Note that, if numerous random variations and strict selection of optimal routines are assumed, the Neo-Darwinian model can be compatible with equilibrium models of microeconomics. See Alchian, 1950; Hirshleifer, 1977).

The current version of the evolutionary framework, however, does not adopt this aspect of Neo-Darwinian view. It assumes that firms are able to change their routines in a non-random way for better survival, although imperfectly and slowly, in response to signals from the environment. In other words, the evolutionary model of this paper emphasize internal selection process, whereas the ecological version emphasizes external selection. As mentioned before, however, my framework does not say that such changes of routines are always preceded by rational plans or foresight; it features the system emergence instead.

To sum up, the present evolutionary framework shares the basic logical structure with Neo-Darwinian models of biological evolution and its application to theories of the firm at the general scheme level, but it is by no means Neo-Darwinian at the level of specific scheme. The latter emphasizes random variations and external selection, recognizing the latter as a dominant force for system formation; the former emphasizes emergent variations and internal selection, emphasizing interactions between firms' distinctive capabilities and historical imperatives.

System Energence and Evolutionary Capability

Multi-Path System Emergence Defined

Based on the evolutionary framework mentioned above, I explore two main concepts for analyzing operation-based capability-building: multi-path system emergence and evolutionary learning capability.

First, let's think about a conceptual framework that may explain long-term formation of a form's operation-based competency. For example, the overall Toyota-style manufacturing competency gradually evolved throughout the second half of the twentieth century as a cumulative result of changes of individual routines. Unlike the cases of continuous process improvements (i.e., Kaizen), however, it is difficult to find a commonality among these

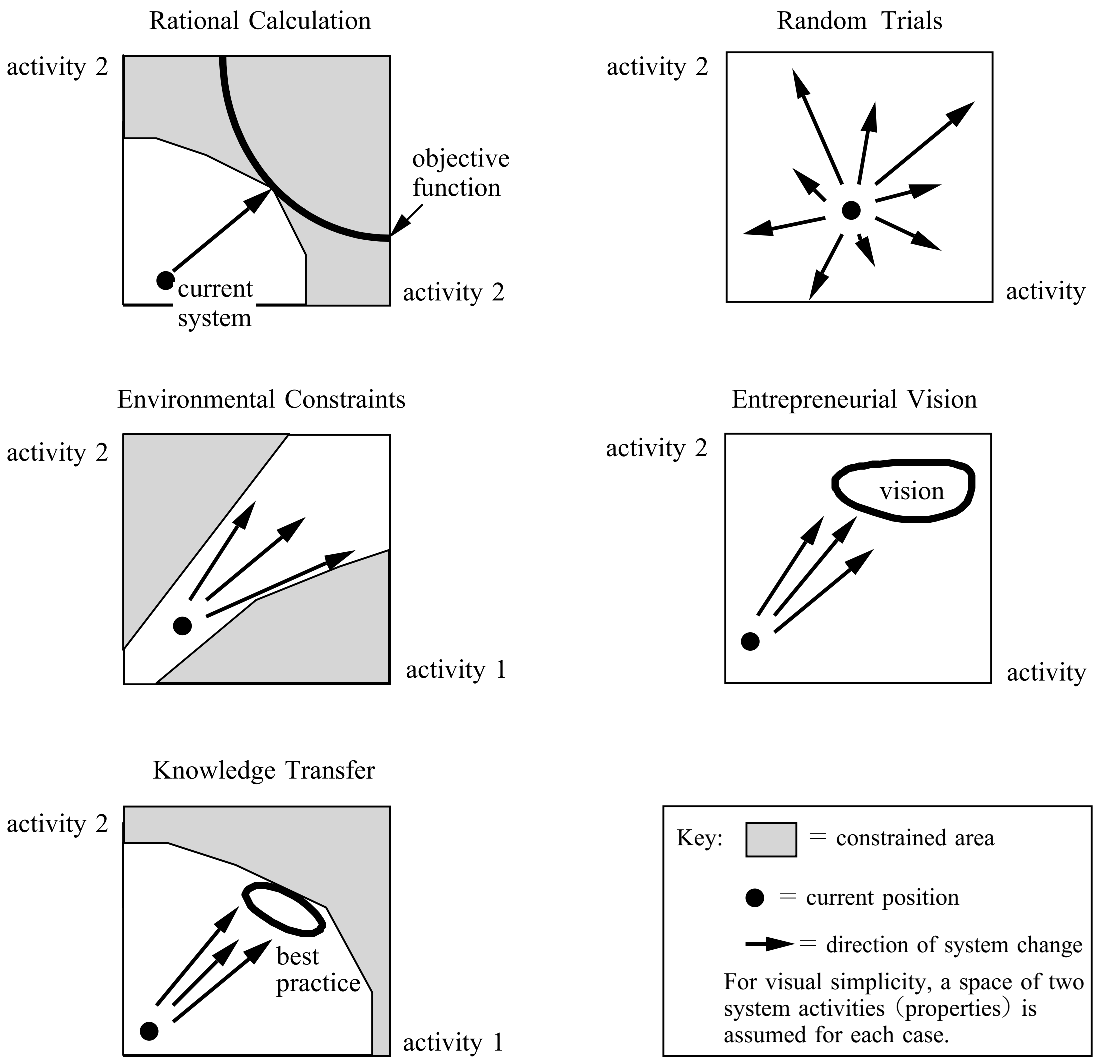
5 Such recent literature as Chandler (1990), Prahalad and Hamel (1990) and Teece, Rumelt, Dosi and Winter (1994) mainly analyze the multi-product or multi-industry situations.

6 Abernathy (1978), Hayes and Wheelwright (1984), and Hayes, Wheelwright and Clark (1988) are among the exceptional cases that included both total system and dynamic perspective, but they did not make an explicit connection to evolutionary theories of firms or organizations.

"histories of routines," in terms of patterns and timing. Instead, the overall process of overall competence development tends to be seen as a complex network of events that contains random chances, ex-ante rational decisions, environmental constraints, unintended successful trials, unsuccessful trials, and so on. Such social system changes are driven mainly by intentional human actions, but they may result in unintended consequences[7]. The process of the change may be explained after it happened, but it is difficult to predict the pattern beforehand. I call this complex and dynamic phenomenon multi-path system emergence.

Generally speaking, a new manufacturing routine gradually emerges as a result of a complex interactions of firms and environments, in which firm-specific capability may play only a partial role. In other words, system emergence can occur through a number of different paths, and a combination of them may be required to explain a particular system change. In my evolutionary framework for analyzing a manufacturing firm, I include the following paths (see Figure 1):

Figure 1 Multi- Path System Emergence



Source: Modified and adopted from Fujimoto (1995) "A Note on the Origin of the 'Black Box Parts' Practice in the Japanese Motor Vehicle Industry." In Shiomi, H., and Wada, K. Fordism Transformed, Oxford University Press.

7 See Merton (1968) for this notion, which is related to his discussion about "latent functions" and "dysfunctions."

Random trials: Those who take this path believe that an organization's trials are a matter of pure chance. A lucky one gets a better system, while an unlucky one gets a poor one — so in that case, you might as well try everything.

Rational calculation: Here decision-makers deliberately choose a new course of action that satisfies or maximizes an organization's objective function; they examine feasible alternatives based on their understanding of environmental constraints and capability limits[8]. This is the ex-ante rational problem-solving many managers believe is the only way to create successful change.

Environmental constraints: Decision-makers detect certain constraints imposed by objective or perceived environments, and voluntarily prohibit a certain set of actions. The constraints may be objective (e.g., laws and regulations), or they may be "self-restraints" based on managerial perception of the environment (e.g., perceiving that the market is rapidly diversifying, planning an ambitious product proliferation to match this perception, and facing the constraint of a current shortage of engineers.).

Entrepreneurial vision: A desirable set of activities is directly chosen by entrepreneurs, based on their visions, philosophies, or intuitions without much analysis of organizational 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) or across industries. Also, the transfer may be a "pull" type, in which the adopter-imitator of the system takes initiative, or it may be a "push" type, in which the source organization is the driving force behind the transfer.

In a word, multi-path system emergence, to the operators of the system in question, means a situation in which they cannot predict which one of the above paths takes place in the next system change. It is a complex and irregular combination of both intended and unintended system changes, as opposed to pure randomness (i.e., neo-Darwinism) or pure foresight (i.e., teleology), as the genetic logic for system variations.

The word "emergence" or "emergent" has been used by a number of scholars in biological evolution (e.g., Lloyd Morgan), sociologists and general system theorists (e.g., Parsons, 1937; Weinberg, 1975), and business academics (e.g., Mintzberg and Waters, 1985)[9]. Across these various disciplines, emergence implies a certain system trait that cannot be explained from the behavior of its constituent parts alone or predicted from the previous states of the system due to its complexity[10]. Its nuances may be somewhat different case by case, but my notion of "system emergence" shares this with them: it rejects the rational optimism that system change can be entirely controlled by purposeful plans that exist prior to the changes; it also denies the cynical notion that social system change is merely a stochastic process, a long-term accumulation of random accidents with little connection to human efforts.

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8 Neoclassical decision theory further assumes that the economic actors are equally capable and face the identical environment.

9 See, for example, Weinberg (1975). For application of the concept of emergent process to organizations and management, see Mintzberg and Waters, (1985). In the fields of natural science, so-called chaos theory is a similar attempt to explain apparently disorderly, irregular, or irregular phenomena by subtle interactions between deterministic processes and random processes (see, for example, Hall, 1991, ed.). The current paper does not try to apply this stream of research directly to social systems, however.

10 According to von Bertalanffy (1968) and Weinberg (1975), the complexity of system behaviors stems from interactions between a "medium number" of elements of the system, rather than random process of a large number of objects or mechanistic process of a small number of objects.

Three Layers of Organizational Capabilities

In applying the concept of organizational capability to the case of operation-based competencies in manufacturing systems (e.g., at Toyota), I propose the following three-layer conceptual framework: *routinized manufacturing capability:* a set of organizational routines that affects the level of competitive performance in a steady state; *routinized learning capability:* a set of organizational routines that affects the pace of continuous performance improvements (as well as recoveries from frequent system disruptions or deterioration); evolutionary learning capability: a non-routine ability that affects creation of the above capabilities themselves[11] (Table 2). The first two are organizational routines that have been analyzed by much of the past literature; but the last category is a new and non-routine concept.

Table 2　Three Levels of Manufacturing Capability

	basic nature	influence on:	interpretation
routinized manufacturing capability	static & routine	level of competitive performance (in stable environments)	firm-specific pattern of the steady-state information system in terms of efficiency and accuracy of repetitive information transmission
routinized learning capability	dynamic & routine	changes or recoveries of competitive performance	firm-specific ability of handling repetitive problem solving cycles or a routinized pattern of system changes
evolutionary learning capability	dynamic & non-routine	changes in patterns of routine-capability	firm-specific ability of handling the system emergence or the non-routine pattern of system changes in building the above routine capabilities

Routinized Manufacturing Capability

The first layer of this framework — routinized manufacturing capability — refers to a stable pattern of a set of productive resources, as well as their repetitive interactions, which creates firm specific advantages in competitive performance at a given point in time. For instance, if a factory operates with a consistently lower number of defective parts per million compared with its competitors, and if certain defect-preventing routines such as *poka-yoke, jidoka, andon,* 5-S are implemented more thoroughly by this factory than the others, we can infer that this set of routines is the factory's routinized manufacturing capability[12]. In an industry where repetitive production is more or less the dominant mode, a stable level of manufacturing performance in stable environments implies that such sets of organizational routines exist.

Further, by applying the informational view mentioned earlier (Fujimoto, 1999), we can reinterpret routinized manufacturing capability as a pattern in a steady-state information processing system by which given product design information is repetitively transmitted in a more effective, accurate, efficient, and/or flexible manner than that of its competitors. For instance,

11　Similar concepts include static versus dynamic routines (Nelson and Winter, 1982), absorptive capacity (Cohen and Levinthal, 1990, 1994), as well as dynamic capability (Teece and Pisano, 1994). The current concept of evolutionary capability is different from these similar concepts in that the former emphasizes non-routine and emergent nature of the process for creating routines.

12　Note that these routines may not only realize lower levels of in-process defects and field defects, but also facilitate problem recognition and thereby trigger continuous improvement (kaizen) activities, which is a part of the improvement capability discussed later on. In this way, the two types of routine-capabilities tend to overlap in the real shop floor setting.

poka-yoke, jidoka, andon, and 5-S can be reinterpreted as a set of routines that jointly enhance accuracy of repetitive information transmission on the shop floor from the production process to the products. In other words, a routinized manufacturing capability refers to a firm-specific set of organizational routines that control the information assets in the manufacturing system, as well as repetitive patterns of information transmission among them. In a static environment, where it is possible to ignore changes in market needs and internal system disruptions over time, a high level of routinized manufacturing capability would be a sufficient condition for a stable level of high manufacturing performance. Note, however, that a static environment may not be a realistic assumption.

Routinized manufacturing capability can be defined for each dimension of competitive performance: factor productivity, throughput time, design quality, and so on (Fujimoto, 1999). But also note that a firm's ability to achieve consistently high performance in multiple dimensions *at the same time* may be even more important for its survival and growth. For example, as William J. Abernathy notes, some firms may improve productivity by sacrificing flexibility; others may improve conformance quality while lowering productivity[13]. When such trade-offs between two dimensions are commonly observed in an industry, a firm that successfully reduces or eliminates such a dilemma may be able to outperform its competitors in both of the competitive parameters at the same time.

Routinized Learning Capability

The second layer — routinized learning capability — refers to a firm's specific ability to change the manufacturing system in a frequent and regular manner to improve functionality. Frequent incremental changes of a firm's products or processes (which allow it to compete more effectively) imply that the firm has a certain routinized learning capability — an organization's ability to conduct *Kaizen,* or continuous improvements. And when a manufacturing firm faces frequent deterioration or disruption of their products or processes, and when that firm recovers from such problems more effectively and speedily than competitors, we can also infer such a company has this capability.

From an information point of view, an routinized learning capability is essentially a set of organizational routines for renewing a firm's information assets for better adaptation in a dynamic environment, one in which product obsolescence and disruptions of production processes are common. For instance, suppose that defect rates at one factory, measured by parts per million, are decreasing continually and at a higher rate than at rivals, over an extended period, and that there is also evidence that this factory installed and implemented TQC (Total Quality Control) and TPM (Total Productive Maintenance) programs more effectively than others over the same period. One may infer from these observations that this manufacturing firm has a certain routinized learning capability.

Again, by applying the information processing perspective, we can refer to this capability as organizational problem-solving — or a firm-specific ability to perform routinized problem-solving cycles more effectively than competitors. In the context of a manufacturing system, a standard problem-solving cycle refers to a heuristic routine that converts problem information (input) into solution information (output). Generally speaking, firm's routinized learning capability consists of the following sub-capabilities[14]:

Problem Identification: A system's ability to reveal and visualize problems, diffuse prob-

13 See Abernathy (1978) for the concept of "productivity dilemma."

14 A standard linear model of problem solving is applied here (e.g., Simon, 1969, 1976; March and Simon, 1958).

lem information to problem solvers, and to keep individual members conscious of problems—as well as the willingness of organizational members to accept higher performance goals.

Problem Solving: The ability to search, simulate, and evaluate the alternatives effectively; to coordinate knowledge, skills, responsibility, and authority for solving problems; to diffuse tools for problem solving throughout an organization; to share knowledge of alternative action plans and their effects; to share evaluation criteria.

Retention of Solutions: The ability to formalize and routinize, quickly and accurately, new solutions in standard operating procedures, maintaining and retrieving them effectively, thereby providing stability for organizational members who internalize the solutions[15].

In an industry where repetitive production of multiple products is common — such as in automobile manufacturing — a firm's routinized learning capabilities can be observed in at least two areas. First, continuous process improvements occur on the factory shop floor. For example, a problem-solving routine can be applied to a standard case of total quality control (TQC), kaizen program, and Toyota Production System (TPS). Say, a Toyota group parts supplier has a factory at which Just-in-Time and visual management are thoroughly implemented so that workers and supervisors can easily find defect problems in the production process. At the same factory, workers, supervisors, and engineers consistently follow standard steps for incremental improvements (sometimes called "the quality control story") — from problem definition (theme setting), to root cause analysis, to shop floor experiments for evaluating alternatives, to decentralized selection and implementation of the revised procedure, and to standardization and counter-measures to make sure that they do not go back to the old way. The company may have a standard format of kaizen report sheets for workers to fill in their cases step by step, following this standard sequence mentioned above. Standardized analytical tools may also be constantly used by the shop floor people (e.g., histograms for identifying the critical problem, cause-effect diagrams for finding root causes, scatter diagrams for evaluating effects of the alternatives, and so on).

Second, we can observe product development improve through design quality and product mix. Other things being equal, there may be a higher pace of model renewals. In this case, we can interpret each of the product development stages (i.e., concept generation, product planning, product engineering, and process engineering) as a distinctive problem-solving cycle[16]. At the product engineering stage, for example, informational outputs of the product planning stage — including product specifications, styling, and layout — become its goals (goal setting); product designs are then developed (alternative idea generation); prototypes are constructed according to the designs (model building); they are tested in proving grounds and laboratories (experiment); and the cycles are iterated until a satisfactory result is achieved, when the final engineering drawings are chosen as a solution (selection).

One could argue that the reality of shop floor management and product development is much more complicated, ill-structured, less streamlined, and more ambiguous than what such a standard model of linear problem-solving cycles assumes[17]. For explaining the routinized learning capability, however, the standard problem-solving routine remains relevant. Although the linear problem-solving model may not reflect the actual messiness of the shop

15 Note that retention of solutions can be also regarded as essentially a static capability, since it enables repetitive activation of the same information.

16 The problem-solving cycles are linked to one another so that solutions in the upstream cycles become goals for the downstream cycles (Fujimoto, 1989; Clark and Fujimoto, 1989, 1991).

17 Alternative frameworks, for example, include the "garbage can" model (March and Olsen, 1976; March, 1988). See, also, von Hippel and Tyre (1993).

floor, an organization that imposes a problem-solving schema on this confusing reality is still likely to improve its performance faster than other organizations that have not established such routines. In other words, a firm with a consistent problem-solving routine throughout the organization is likely to achieve a better result in terms of continuous improvements. For that reason, the core element of a firm's routinized learning capability is a routine for standard problem-solving cycles.

Evolutionary Learning Capability

The third layer of this framework, evolutionary learning capability, is not so easy to observe in the everyday workings of a company. It means a firm's distinctive ability to create a set of effective (i.e., ex-post rational) organizational routines in the long run faster and earlier than its competitors. Thus, to the extent that the changes in the organizational routines can be regarded as multi-path system emergence, the evolutionary learning capability means *a firm-specific ability to cope with multi-path system emergence,* or a complex process of capability building, which is neither totally controllable nor predictable.

Note here that the evolutionary learning capability is not a routine itself[18]. That is, the routinized learning capability and the evolutionary learning capability, while both are dynamic, should be distinguished from each other. The former deals with routinized or regular patterns of system changes, whereas the latter is related to higher-order system changes that themselves are rather irregular and infrequent, and are often connected with rare, episodic and unique historical events[19].

To the extent that firm-specific patterns of productive performance and operation-based capability are observed, *differences* in each firm's evolutionary learning capability do matter. In particular, we can distinguish the following two aspects of evolutionary learning capability:

(1) *Intentional (pre-trial) learning capability:* A firm's ability to find, experiment with, and acquire new organizational routines more effectively than competitors. This may include an ability to calculate potentially effective trials rationally, or an entrepreneur's intuitive ability to envision effective trials.

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18 There is always a danger that such a logic leads to an infinite chain of backward explanation (capability of capability of capability building, and so on). The current definition of three layer capabilities tries to avoid this problem by giving each construct concrete definition, rather than simply calling them meta-routines. Thus, improvement capabilities handle repetitive routine changes, while evolutionary capabilities cope with non-routine emergent changes. Also, practically, it does not mean much to discuss capability of building evolutionary capabilities, because the creation of the evolutionary capability itself is likely to be a unique series of historical events, whose stable pattern cannot be analyzed in a meaningful hypothesis-testing way. The current paper, being aware of this problem, will not try to go further backward and explain explicitly why a company like Toyota could historically build a certain evolutionary capability. It would be impossible, in the first place, to explain such rare events by the concept of the organizational capability.

19 The idea of multi-layer structures in organizational capabilities, routines, programs, knowledge, learning, etc., is not particularly new in the literature of organizational studies. The concept of "initiation" as a creation of new programs (March and Simon, 1958), "structuration" as conditions governing continuity or transmutation of the structure of rules and resources (Giddens, 1984), "double loop learning" (Argyris and Shon, 1996), "higher level learning" (Fiol and Lyles, 1985), for example, are all assuming such a multi-layer structure. The current definitions of improvement versus evolutionary capabilities are somewhat different from the above ones in that the former emphasize the distinction between repetitive regular changes and emergent irregular changes of the system in question.
Also note that the distinction between the improvement capability and the evolutionary capability is different from the classical distinction between the ability to handle incremental innovations and that for radical innovations (Abernathy and Utterback, 1978; Hayes and Wheelwright, 1984): The evolutionary capability discussed here is not an ability to perform a one-time big system change, but an ability to cope with an emergent process over an extended period.

(2) *Opportunistic* (*ex-post*) *learning capability:* But what if trials for a new capability are made inadvertently, and turn out to be effective in competition? In this case, a firm with a strong ex-post capability can still create specific advantages for itself, through its ability to grasp the potential competitive consequences of inadvertent trials, and then to routinize and retain successful trials.

Even when competing companies do not differ in intentional (pre-trial) learning capabilities or their ability to problem-solve, one firm may still be able to outperform the others by possessing better opportunistic (ex-post) learning capabilities than the others.

To sum up, a firm's evolutionary learning capability is its ability to manage the multi-path system emergence processes of routine-capability building better than its competitors. As such, it is a non-routine dynamic capability embedded in the organization.

Application: Operation-based Competency at Toyota

Basic Facts about History of Automobile Manufacturing

So far I have proposed the concepts of multi-path system emergence and evolutionary learning capability for analyzing dynamic aspects of a firm's operation-based competency. Now we try to apply them to the history of manufacturing routines in the automobile industry.

Let's start by summarizing the following historical phenomena on the world automobile industry as stylized facts. First, a group of Japanese firms had demonstrated significantly higher levels of manufacturing performance in the world auto industry by the 1980s. Second, high-performance Japanese manufacturers like Toyota improved certain aspects of their performance faster and more consistently than other firms during an extended period prior to the 1980s. Third, the high levels of performance and pace of continuous improvements appeared to stem from an overall manufacturing system, rather than individual techniques or practices. Fourth, the Toyota-style system was not created all at once, but gradually and cumulatively evolved, mainly between the 1940s and 1980s (Cusumano, 1985; Fujimoto, 1999).

Past literature of operations and productive performance in this industry also identified universally prevalent, region-specific, and firm-specific patterns of manufacturing capability all exist at the same time (Clark and Fujimoto, 1991). That is, the following conditions all affect evolution of operation-based competence:

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

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

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

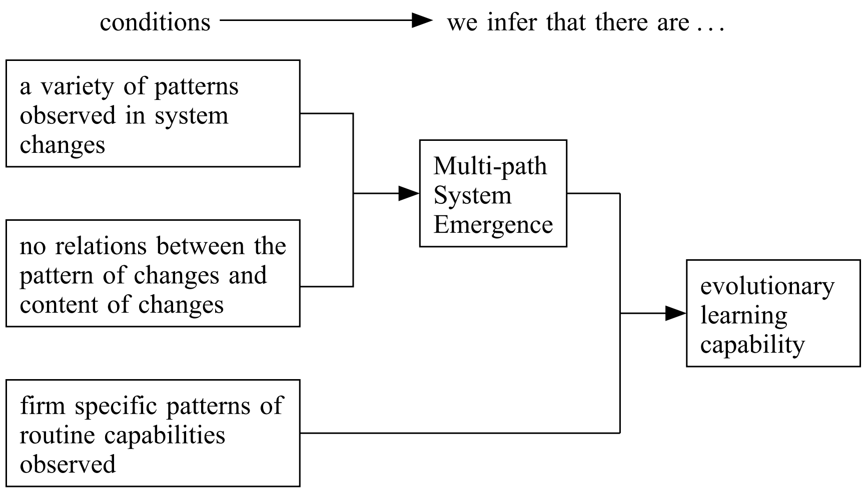
Thus, although pure chance and historical imperatives often play important roles in the system emergence and capability-building process, a company may still be able to build certain manufacturing capabilities faster and more effectively than competitors through a strong evolutionary learning capability. For example, historical imperatives may explain why the Japanese auto-makers in general acquired certain region-specific capabilities, but they do not explain why certain Japanese companies like Toyota have had better capabilities than others.

Operational Definitions

With the basic empirical observations and key concepts laid out, let's now apply this scheme to the actual case of operation-based competency in Toyota-style manufacturing system. For this historical analysis, we have to operationally define the concepts of multi-path system emergence and evolutionary learning capability as follows (Figure 2).

(i) When a wide variety of system change patterns (rational calculation, environmental constraints, entrepreneurial vision, knowledge transfer, random trials) are observed historically, (ii) and when no correlation is observed between the patterns of the system change paths and the changing systems themselves, we regard that the system in question is an outcome of a multi-path system emergence. In addition, when we also observe that the resulting system (i.e., a set of routines) demonstrate stable and firm-specific competitive performance, we infer from these facts that the firm had a certain evolutionary learning capability.

Figure 2　Operational Definition of System Emergence and Evolutionary Capability



Summary of the Routines' Histories

Based on the above operational definition of system emergence and evolutionary learning capability (see Figure 2 again), the author explored the evolution of various core elements of the Toyota-style system (Fujimoto, 1999), or operational routines. Just-in-Time, mechanisms for productivity improvement, multi-tasking, flexible production, Total Quality Control, suppliers' design capability, and the heavy weight product manager system are examples of such routines, whose histories may be investigated one by one.

Although the details of the historical analysis are omitted in this paper (see Fujimoto, 1999), the result may be summarized with regard to the pattern of manufacturing routines characterized as the "stylized facts" mentioned earlier — the coexistence of universally adopted routines, region-specific routines, and firm-specific routines.

(1) Factors Affecting Universally Adopted Routines:

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

1930s and ’50s, Toyota’s consciousness of imaginary competitive pressures persisted.

Direct and indirect adoption of Ford system: Motivated partly by the above perception 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, the Taylor system, supervisor training program, and statistical quality control. A pure dichotomy between the Ford system and the Toyota system is therefore misleading.

(2) Factors Affecting Region-specific Routines:

Benefits of Forced Growth: Some of region-specific historical 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 such responses were not recognized as competitive weapons when the firms 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 Forced Flexibility: The imperative of forced flexibility in a 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 a necessary evil to cope with the fragmented market, rather than a measure for international competition, when the capabilities were first built. It should also be noted that, as is obvious from the comparison of the Japanese and U.K. production systems, fragmented markets do not automatically create effective flexibility.

Benefits of Lack of Technology: While excessive use of high-tech automation equipment often became obstacles against productivity improvement in many of the Western auto makers of the 1980s, the effective Japanese makers apparently avoided such problems. This may be partly because they consciously rejected the temptation of 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.

Benefits of Intended Knowledge Transfer: Region-specific patterns of capabilities may also emerge when intra-regional knowledge transfers are more dense and frequent than interregional ones. The supplier networks shared by the Japanese firms was one such transfer instrument. Intense competition between domestic makers during the 1960s and 1970s may have also facilitated their efforts to learn from domestic competitors.

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

Benefits of Incomplete Knowledge Transfer: Although the Japanese auto firms tried to adopt many of the practices and techniques from the US mass producers, some of them were incomplete due to the historical imperatives mentioned above and lack of the firms’ absorption capacities. In this sense, the Kanban system may be regarded as an incomplete version of the conveyer system, the U-shape machine layout as an incomplete transfer machine, and Jidoka as incomplete adaptive automation. The very incompleteness of the transfer may have facilitated its subsequent diffusion through the entire system.

(3) Factors Affecting Firm-specific Routines:

Benefits of Self-fulfilling Visions: Firm-specific entrepreneurial visions sometimes played an important role in building distinctive manufacturing capability. This was particularly the case when an apparently unrealistic vision triggered self-fulfilling efforts to achieve bold objectives. Kiichiro Toyoda in the 1930s and 1940s played a pivotal role in advocating cost reduction without economy of scale, catch-up with Ford, and the Just-in-Time philosophy. Nissan of those days did not have his counterpart.

Benefits of Linkage to Other Industries: Toyota's inherent connection with the textile industry may have facilitated knowledge transfer from it (particularly through Taiichi Ohno) and helped create the auto maker's competitive advantages in production control techniques.

Advantages of Opportunistic (Ex-Post) Learning Capability: Even when no firms recognized the potential competitive advantage of the new system when they first tried it, some could still create firm-specific advantages by exercising an *opportunistic (ex-post) learning 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 Japanese auto makers faced similar environmental pressures for adopting the black box parts system in the 1960s, only Toyota appears to have created a system that could fully exploit the potential advantages of this practice. Although all the Japanese auto makers accepted aircraft engineers after the war, Toyota was the only company that institutionalized the 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 some of them materialized this potential luck through firm-specific evolutionary learning capability.

Interpretation: Toyota's Evolutionary Learning Capability

Following the operational definitions of multi-path system emergence and evolutionary learning capability mentioned earlier in Figure 2, the foregoing result can be summarized in Table 3, in which Toyota's capability building cases were classified according to types of routines and types of paths.

It is now clear from this analysis that:

(i) There were a variety of system change paths for each main component of the Toyota-style manufacturing system (see the variety of explanations at each column of Table 3);

(ii) There was no clear correlation between the nature of the routines and the types of the paths (compare the patterns of explanations across the columns of Table 3).

Therefore, by applying the operational definition specified in Figure 2, I argue that Toyota's routine capability building can be characterized as a *multi-path system emergence* and that Toyota, creating distinctively competitive routines though the emergent process, possessed an *evolutionary learning capability.*

The evolution of the Toyota-style manufacturing system can be characterized by a multi-path system emergence in this sense. Although the official corporate history portrays Toyota's success as a combination of entrepreneurial vision and rationally controlled follow-through, the company's ability to "seize the day" when the unforeseen occurred — its superior

Table 3 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 60 s		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

evolutionary learning capability — may be more important in the long run (Fujimoto, 1999).

Implication and Conclusion

Related Concepts

Now that I have proposed the concepts of evolutionary learning capability and its application to an actual case of operation-based competency, let's link the present framework to related concepts for explaining emergence of operation-based competency.

Emergent strategy: Mintzberg's emergent strategy (as well as Quinn's logical incrementalism) is a powerful concept that can explain a significant fraction of my historical materials (Mintzberg and Waters, 1985; Quinn, 1978). Indeed, ex-post evolutionary capability includes ability to realize emergent strategy better than other firms as an essential part. Note, however, that the concept of multi-path system emergence is a broader than the emergent strategy, as the former also includes the deliberate strategy as a possible path.

Organizational Learning: Evolutionary learning capability is also closely related to the concept of organizational learning[20]. Yet there are some important differences between it and existing organizational learning concepts. Organizational learning assumes implicitly regular patterns of learning (problem solving routines), repetitions (learning by doing), or the prior existence of an overt intention to learn (learning from others through benchmarking). The concept of evolutionary learning capability does not assume these conditions, since it includes irregular, non-repetitive, and unintended learning factors. Evolutionary learning capability, in this context, implies an ability to acquire effective routines in any number of ways, even if it is hard to predict what types of learning opportunities will emerge and when. These opportunities may include organizational learning from deductive theories, learning from others, learning by intentionally doing — but they may also include "unintentional" learning through inadvertent actions.

Problem-solving: The process of multi-path system emergence does include the standard problem-solving cycles discussed earlier, but problem-solving heuristics cannot always explain system emergence and a firm's evolutionary learning capability. The regular sequence of problem identification — solution — retention may not exist; in many cases, trials of solutions precede problem recognition, as James G. March and Johan Olsen point out in relation to their "garbage can model."[21] Solutions to certain non-competitive problems may subsequently and inadvertently become solutions for competitive problems. For instance, Toyota increased its reliance on suppliers' engineering activities in the 1960s, which managers and engineers at the time apparently believed was a solution to alleviate the problem of mounting work load for Toyota's in-house engineers. Yet this specific solution to workload problems had unintended consequences for competitive performance. In fact, relying on suppliers' engineering activities became a major competitive weapon for Toyota and other Japanese auto makers by the 1980s, because it facilitated cost saving through component design for manufacturing (DFM) and product development cost/time saving.

Rationalism: An evolutionary perspective recognizes that ex-ante rational human actions

20 To the extent that organizational learning is "encoding inferences from history into routines that guide behavior" (Levitt and March, 1988) or "improving actions through better knowledge and understanding" (Fiol and Lyles, 1985), evolutionary capability may overlap the concept of a certain higher-order learning ability to change routines for learning or values (Argyris and Shon, 1996; Fiol and Lyles, 1985). For concepts and definitions of organizational learning, see, for example, Fiol and Lyles, 1985, Levitt and March, 1988, and Argyris and Shon, 1996.

21 See March and Olsen (1976) and March (1988).

(either as described by the "perfect rationalism" of neoclassical economics, or the " bounded rationalism" of Herbert Simon[22] may create organizational changes, but such an approach in a complex system only represents one of many possible paths. Entrepreneurial visions, which business historians tend to emphasize, play an important part — yet so do environmental constraints, and the many external forces that can affect system changes for good or ill.

The Remaining Questions

The present paper interpreted a firm's evolutionary learning capability as its ability to perform both ex-ante (intentional) learning and ex-post (opportunistic) learning. I paid a particular attention to the latter: A company with a high ex-post (opportunistic) learning capability, like Toyota, converts miscellaneous existing solutions, many of which are unpolished, to a set of distinctive routine capabilities in product development, production, and purchasing.

What are, then, the organizational properties that may facilitate the solution-refinement cycle? Again, systematic empirical research will be needed to detail this, but it is my impression that, after many contacts with Toyota employees, they view new situations in daily life — whether new problems, solutions elsewhere, partial solutions to the present problems, or chance events — as potential opportunities to improve competitiveness more often than those in other firms. The original trials may be pure luck or unintended consequences rather than intended and realized success, but a firm with many "prepared" people who associate everything with its competitive effects, may be able to recognize the competitive value of such trials and exploit them more effectively than rivals (Cohen and Levinthal, 1990, 1994).

Other questions follow naturally from the above discussion: *How was the evolutionary learning capability formed* in the first place in a particular company? Where did such a company-wide "competition-consciousness" or "prepared mind" come from in Toyota? These are intriguing questions, but there are no clear answers. Some say that the spirit of Kiichiro Toyoda or even Sakichi Toyoda was long retained in the employees' attitudes; others claim a distinctive culture of eastern Aichi prefecture (traditionally called Mikawa) shaped up their tenacity and concentration. Both are plausible, but neither is convincing alone. After all, the formation of the evolutionary learning capability itself is so rare that it is extremely difficult to analyze as a subject of social science. For now, suffice it to say that historical circumstantial evidence leads us to infer that Toyota had distinctive evolutionary learning capabilities, at least up to the 1980s.

Conclusion

This paper presented an evolutionary framework for analyzing a certain type of long-term process innovations. By introducing such concepts as multi-path system emergence and evolutionary learning capability, the paper argued that the cumulative process innovation of a manufacturing system at Toyota Motor Corporation may be explained more persuasively by applying this present framework of multi-path system emergence and evolutionary learning capability.

Based on empirical and historical researches of the world automobile industry to date, we know that a wide variety of system performances and practices exist at different firms, and that these systems have changed in non-routine ways over time. Thus, I believe the evolutionary framework proposed I this paper substantially adds to our understanding of why certain manufacturing practices have emerged at Toyota.

22 Simon (1969, 1976).

A company's decision-makers should certainly attempt to solve problems rationally; but they also should not assume rational plans always solve those problems. The actual process of system change is essentially emergent. No matter how successful a company has been in the past, it needs to develop an organizational culture of "preparedness": It must convert both the intended and unintended consequences of its actions, the lucky breaks and the well-laid plans, the temporary successes and failures, into long-term competitive advantage. This is the key ingredient of an effective evolutionary learning capability. After all, fortune favors the prepared organizational mind[23].

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23 The original phrase was made famous statement by Louis Pasteur: "Fortune favors the prepared mind." The relevance of this phrase was suggested to me by David A. Hounshell (Carnegie Mellon University), as well as a paper by W. M. Cohen and D. A. Levinthal, "Fortune Favors the Prepared Firm" (*Management Science,* Vol.40, No.2, 1994.)

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