4 Knowledge-Based View of Radical Innovation: Toyota Prius Case

Ikujiro Nonaka and Vesa Peltokorpi

Introduction

Technological changes occur through nonlinear cycles of incremental and radical innovations. In addition to incremental improvements on the existing technology and technological processes, occasional radical innovations emerge, with potentially devastating effects on the old technological and even economic systems (Schumpeter 1934). While potentially providing organizations with rare and inimitable sources of competitive advantage (Barney 1991), radical innovations are characterized by high risk and uncertainty. Because of the inherent uncertainty, companies tend to accumulate knowledge, techniques, and skills through incremental improvements.

The potential value of radical innovations for future technologies, products, and services has attracted wide interest among scholars (for example, Von Hippel 1988; Anderson and Tushman 1990; Damanpour 1991; Hage and Hollingsworth 2000; Van de Ven *et al.* 1999). Those studies identify important macro-level factors, but tend to perceive innovation as a *thing*. As a consequence, relatively little research examines innovation *processes*, defined as 'nonlinear cycle[s] of divergent and convergent activities' (Van de Ven *et al.* 1999: 16). Further focus on processes is important in order to identify the particulars that contribute to radical innovations as things. Knowledge-creation theory, with its dynamic process view, is used in this chapter to explain radical innovation processes (Nonaka 1991, 1994; Nonaka and Takeuchi 1995; Nonaka and Toyama 2002).

Radical product innovations are products previously unavailable, products that improve performance significantly, or products removing some undesired quality (Hage and Hollingsworth 2000). One recent radical innovation of importance is the first commercialized hybrid electric vehicle, the Prius. The introduction of this vehicle in December 1997 marked a radical shift from more than a century of dominance by the internal combustion engine. In addition to introducing the revolutionary vehicle, Toyota Motor Corporation (hereinafter 'Toyota') made during the project radical improvements to new product-development efficiency. The development from an early prototype to mass-produced vehicles took only fifteen months. The case shows how idealistic projections and careful selection of people tie various knowledge domains into a dynamic coherence.

Four sections follow this introduction to the chapter: the basic tenets of the knowledge-creation theory are explained; the discussion moves from the *ba* (shared context in motion) to the SECI knowledge conversion process and the synthesis of the *ba* and the SECI; the Prius case is used to illustrate how the *ba* and the SECI act as a dynamic coherence in knowledge creation; the chapter closes with conclusions and managerial suggestions.

Context and process of knowledge emergence/creation

Knowledge-creation theory is based on related ontological and epistemological assumptions (Nonaka 1994; Nonaka and Takeuchi 1995). The time-space specific interactions in knowledge-creation are dialectical because the actors influence, and are influenced by, their surrounding reality. Two dialectical relations are germane to radical innovation: one between inner and outer dialectics, and the other between thought and action. Positivist management science can be said to ignore the context specificity and dialectic relationships because of the subject–object duality. As the world is frequently explained through structured immobility, little is known about knowledge-creation processes. In contrast, we describe the creation of knowledge as a dynamic phenomenon through the *ba* and the SECI process of knowledge conversion.

Context for knowledge emergence (ba)

A duality of objective structures and subjective consciousness exists in Anglo-American social theory (Brown 1978). These domains meet in organizations inhabited by subjective individuals. As objective structures shape human action in the structural approach, little focus is directed on the self-directing and dialectic human consciousness. But the human inner (processes internal to the individual) and outer (interactions between the individual and the external world) dialectics can instead be assumed to have an impact on the surrounding reality, which is why organizations do not always live up to their rational promise. An easy way out for many scholars is to explain organizations objectively, and to disregard intentionality, values, and other subjective human attributes. In contrast to objective positivism, the *ba* concept seeks to transcend some of this objectivity–subjectivity opposition (Nonaka and Konno 1998; Nonaka and Toyama 2002, 2003).

The paradox in objective theories is simultaneous explanation of structures suited to routine and non-routine tasks (Thompson 1967). Although scholars have sought to solve this puzzle over the years, objective explanations put humans into a secondary position. While positivist assumptions are based on a priori notions of human behavior, we claim, as do phenomenologists and pragmatists, that human thought and action are inherently subjective. Human actors can be explained through universal and idiosyncratic components (Hayek 1948), and have various, seemingly rational, means to reach their ends. Both means and ends are influenced by time-space in which humans draw on their values or ideals to determine appropriate means in context-specific action (Rescher 1987, 2003). The appropriate means to reach the goals is a matter of intelligent pursuit in which meanings are created by visualizing the projected act in the future (Schutz 1932). The objective structures may thus guide and create tendencies, rather than law-like causalities.

Organizations can also be described as intertwined collections of meaning structures (Nonaka and Konno 1998). By consciousness, individuals are united with the surrounding and unfolding reality. Understanding how reality 'works' is possible only through pure experience beyond the subject–object separation (Nishida 1970). New meanings at the individual level emerge from ontological nothingness or selflessness; the self itself is realized through the act of experiencing. That is, open *ba* generates new meanings. The highest form of knowing takes place from a point at which the knower and the known are one. Realization of the self and the surrounding reality as an absolute nothingness means that no relationship is exempt from the dialectic of coming to be and passing away. In the purest form, nothing exists in *ba* except relationships (Chia 2003). In presenting the individual as an effect of experience and relationships, Kitaro Nishida (1970) characterizes the individual self as a secondary social construction of reality. As the ability to achieve nothingness is a major cognitive achievement, and subject to individual variations, the self-transcending acts of pure experiencing and knowing by becoming can be facilitated through triangular phenomenological roles (Varela and Shear 1999). These roles, connecting inner self with the surrounding reality, are further important for consensual validation and nourishment of new ideas.

The intertwined inner and outer dialectics blur relations between individuals and their surrounding reality. Indeed, the boundaries between self and others, as well as firms and their environment, are essentially open. While the agency-structure interaction is explained in various ways, phenomenologists and structural sociologists agree that humans create knowledge in social interaction, through which they seek to fulfill their projects as embedded and intentional actors (Merleau-Ponty 1962; Giddens 1984). In the process, the surrounding reality both inhibits and provides opportunities to the consciously chosen projects. Humans have an embedded desire for projects that are both realistic but contain unreachable higher aspirations. There is hence a gap between aspiration and attainment. To quote Rescher (1987: 143): 'Optimal results are often attainable only by trying too much—by reaching beyond the limits of the possible. Man is a dual citizen of the realms of reality and possibility. He must live and labor in the one but strive toward the other.' Individuals, as self-promoting actors and parts of social collectives, seek to gain the essence of their surrounding reality through action-reflection dialectics (Polanyi 1952; Heidegger 1962; Schön 1983). The body acts as the medium between the mind and the environment (Merleau-Ponty 1962), which explains why some knowledge used in these projects is acquired through reflecting experiences in direct activities, and some of it occurs at a subconscious level.

The philosophical notion of *habitus* builds on structural assumptions towards shared knowledge (Husserl 1947; Merleau-Ponty 1962; Bourdieu 1985). In contrast to the structural dominance over humans, collective habits are developed over time through the dialectics between selfhood and otherness. *Habitus* can be understood as a kind of mind-less or unconscious orchestration of actions that does not presuppose agency and intentionality (Chia 2004). It is not about blind cultural programming of human behavior nor is it about the spontaneous creativity and intention of willful free agents. Rather, *habitus* as a set of internalized predispositions enables actors to cope with unexpected and changing situations by inducing non-deliberate responses which, while containing a degree of improvisation, reproduce regularities that make most human behavior 'expected' and 'rational.' However, social practice theorists, such as Bourdieu (1985), reject a linear and causal view of action. Instead of assuming that human actions follow structures, humans create space for interactions and the creation of meaning in the *ba* by their knowledge and intersubjectivity. In the supporting context, the interaction, respect for various ideas, and free exchange of tacit knowledge allows the new knowledge to emerge.

The role of an organization is to be a supporting mechanism for knowledge creation by connecting and energizing various *ba*. As tacit knowledge is located in various *ba*, managers create and foster free exchange of knowledge in, across, and between various *ba*. They also connect and rewire knowledge domains. Positioning is important: research estimates that 20 per cent of the actors hold about 80 percent of the network connections (Barbasi 2002). Managers can alternatively use hierarchies and formal power to connect *ba* at various organizational levels to form a greater *ba* (Nonaka *et al.* 2000*a*). It can further be claimed, as in recent research on transactive memory directories, that organizations can create structures enabling employees to use information technology to search and locate knowledge (Peltokorpi 2004). Also, physical places act as supporting contexts for the creation of knowledge (Nonaka and Konno 1998). The interfaces amongst the *ba* evolve through interaction, time, and intersubjectivity.

Firms connect, lead, and organize the interaction among the various *ba* through networks (Nonaka *et al.* 2000*a*). Through their small-world networks, people locate external collaborators with the right knowledge to speed up the product-development process. The small-world network properties enable the coexistence, even in a sparse network, of a high degree of clustering, and of short average path lengths to a wide range of nodes (Watts 2003). Once the structural view of networks is replaced with a relational view, networks act as both the outcome and initial condition of agency. People and firms feed into networks, energize them by their input, and, in turn, are enriched through the networks' content and activity. In contrast to the traditional concept of innovation networks (for example, Von Hippel 1988; Dyer and Nobeoka 2000), the relational network concept is not a way of presenting relations among fixed entities, but is about being itself (Merleau-Ponty 1962). What gives any object its properties as well as its ontology is a set of relations to other entities. This means that individuals, like organizations, are born, act, evolve, and cease to exist because of their networked part of the whole.

Knowledge-creation process (SECI)

Knowledge creation occurs through the dialectics of tacit and explicit knowledge (Nonaka 1994; Nonaka and Takeuchi 1995; Nonaka and Toyama 2002, 2003). Instead of adopting an objective approach to knowledge, the knowledge-creating theory draws from phenomenology, idealism, rationalism, and pragmatism. Knowledge is 'a dynamic human process of justifying personal belief toward the truth' (Nonaka and Takeuchi 1995: 58). The process takes place through the Socialization, Externalization, Combination, and Internalization modes (Figure 4.1).

Direct experiences during the socialization phase enable the accumulation of tacit knowledge. The emphasis on obtaining pure insights from experience embraces the phenomenological philosophy (Husserl 1931; Nishida 1970). The mind gives the accumulated experiences subjective personal meanings. Tacit knowledge is hard to externalize and explain, as there is more to know than can be explicitly communicated through language (Polanyi 1952). It is, therefore, important for actors to embrace contradictions rather than confront them (Nonaka and Toyama 2003; Varela and Shear 1999). The Structuration Theory links humans to the environment (Giddens 1984). Humans perform daily actions through

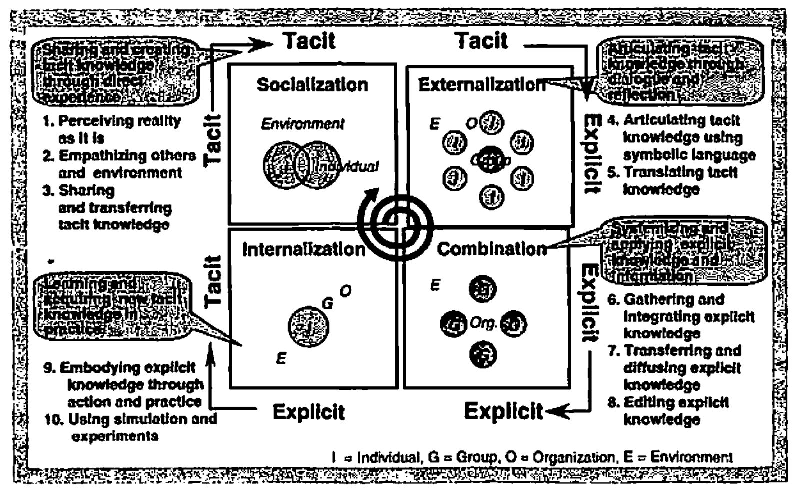

Fig. 4.1. SECI model

practical and discursive consciousness. Where the former refers to tacit stocks of knowledge from which humans unconsciously embrace environment, the latter describes conscious levels of knowing. Like tacit knowledge, practical consciousness reflects humans' being inside of the external world.

During the externalization phase, tacit knowledge is shared through metaphors, dialogues, analogies, and models. Metaphors can be described as the use of words and prototypes outside their conventional meanings. Dialogues can be distinguished from conversations: in conversations, people tender their case through logic, and try to change the opinions of other people; in contrast, dialogues, as 'a stream of meaning flow among and through a group of people,' are based on active listening and openness to changing opinions (Bohm 1990: 1). Important in the process is the diversity of knowledge, which increases the likelihood of the emergence of radical solutions (Hage 1999). Other enablers are intentionality (Searle 1983), love, care, trust (Nonaka and Takeuchi 1995), the embracing of paradoxes, and cultivation of opposite traits.

Firms systematize, validate, and crystallize the externalized tacit knowledge during the combination phase in more explicit forms for collective awareness and practical usage. Firms can, for example, break down concepts into smaller components to create systemic, explicit knowledge. These components are evaluated and validated rationally through their effectiveness. The process includes monitoring, testing, and refining to fit the created knowledge with the existing reality. The combination and distribution of knowledge can be facilitated by information technology, division of labor, and hierarchy.

New knowledge is acquired and utilized through experimentation and discipline during the internalization phase. This phase can be described as a transformational praxis in which knowledge is applied and used in practical situations, becoming a base for new routines (Nonaka and Toyama 2003; Nonaka *et al.* forthcoming). Explicit knowledge, such as product and service concepts, has to be actualized through action, practice, and reflection so that it can really become owned (Nonaka and Toyama 2003). The consequent products work as a trigger to elicit tacit knowledge from customer demand and consumption patterns. External stimulus from customer reactions is thus reflected in the processes, starting a new spiral of knowledge creation.

The movement through the four modes of knowledge creation forms a spiral that becomes larger as it moves up the ontological levels (Nonaka and Toyama 2003). While the boundaries between the modes are claimed to be porous (Tsoukas 1996), growth of social knowledge occurs through the sequence of sensing ⇒ sharing ⇒ systematizing ⇒ utilizing. There is constant interaction between the different levels of analysis, because individuals interact with the environment, and new knowledge changes the societal rules and behavior. The accumulated knowledge, techniques, and skills set the agenda for further innovations that contribute to economic/societal change and the evolution of economic institutions.

Synthesis of context and process

A synthesis between context (*ba*) and process (SECI) enables knowledge creation. Interactions among the various *ba* are created by knowledge visions, which are value-driven articulations of an idealistic praxis for a social collective (Nonaka *et al.* forthcoming). Knowledge visions form a nexus among the past, present, and future, as the past has meaning only as a projection of the future. The future is not a determinate end but opens up a cascade of potentials. Middle managers bridge the top-management visions and the chaotic reality at the front line (Nonaka *et al.* 2000a). They take the roles of instructor, coach, mentor, and coordinator to encourage knowledge sharing, as well as to disseminate information.

While the visible hand of managerial control is occasionally important to speed up processes, the most effective part of power is rooted in language (Alvesson 1996). Managers have the opportunity, more than others, to give meanings to events, and in doing so contributing to the development of norms and values. Pettigrew (1977) describes this as the management of meaning, referring to a process of symbol construction and value use designed both to create legitimacy for one's own demands and to delegitimize the demands of others. Being able to define the reality of others, managers are powerful agents creating shared meanings, ideas, values, and reality through communication and the social construction of meaning.

Toyota Prius case[1]

Toyota has emerged as one of the world's leading automakers since its establishment in 1937. Global sales of Toyota and Lexus brands (combined with those of Daihatsu and Hino) totaled 6.78 million units in the fiscal year 2003. This is equivalent to one vehicle every six seconds. Besides 12 plants and 11 manufacturing subsidiaries and affiliates in Japan, Toyota has 51 manufacturing companies in 26 countries which produce Lexus- and Toyota-brand vehicles and components. As of March 2004, Toyota employs 264,000 people worldwide (on a consolidated basis), and markets vehicles in more than 140 countries. The automotive business, including sales finance, accounts for more than 90 per cent of the total sales, which came to a consolidated 17.29 trillion yen in the fiscal year ending March 2004. Toyota has not recorded an operating loss since it officially started to measure its profits in the 1940s.

Knowledge-based strategy

Although Toyota was, in many respects, successful in the early 1990s, the belief that there was no crisis waiting in the future was itself considered to be a potential crisis. Successes were seen to limit idealistic visioning of future possibilities. In order to avoid the curse of success, top management wanted to face future challenges at an advantage by developing core technology, path-breaking vehicles, and new routines of product development for the 21st century. Without a path-breaking vehicle, it was felt that Toyota would be following a steady path of incremental innovation, rather than moving radically to a new level of existence.

In terms of the trends for future automobiles, top management had long been aware of the demand for cleaner air and greater fuel savings. This value-rational consideration was already explicit in the Earth Charter of 1992, which outlined goals to develop and market vehicles with the lowest emissions possible. Within the charter, the number one action guideline was 'always to be concerned about the environment.' President Fujio Cho made the following statement:

> It bothers me when I'm told that, in the 100 years of automobile development, Japan has not contributed anything. Unfortunately, the starting lines were different, so nothing can be done about this. With respect to the environment, however, the starting line is the same for everyone. Toyota will make every effort so that we can hear that Japan's technology has contributed this much to the environment.

The global environmental concerns and consequent need for low-emission vehicles surfaced relatively late, giving Toyota an opportunity to break old technical systems with revolutionary, environmentally friendly technologies. The company had long worked to reduce emissions in internal combustion engines (ICE) and it was also one of the leading automakers in terms of fuel efficiency.

In reflecting on the Earth Charter, Toyota started to focus more seriously on alternative technologies in 1991. These efforts were stimulated partially by the Zero Emission Vehicle (ZEV) program implemented by the State of California in 1990. Managers realized quickly that car manufacturers need to respond to these increasingly environmental standards. While the company responded to the ZEV mandate with a battery powered RAV-4 in 1996, the car never became a commercial success: high costs and a low operating radius were unsolved problems with battery-powered vehicles. The Electronic Vehicle Development

Department consequently started a systematic study of the hybrid system, combining an engine and a motor. The current Prius chief engineer, Mr Masao Inoue, recalled:

> Back in the early 1990s, when Toyota was developing a business case for hybrid technology, it was decided that the engineering program would need to be done almost entirely in-house. This meant that nearly every bit of design, engineering, parts production, and assembly would be done in-house. No partnerships. No contractors. No suppliers of major components or systems.

The in-house development was considered to enable the gaining of overall knowledge of the system and all included components. Top management was committed to providing the needed resources for the uncertain project. While risky, this approach allowed Toyota to develop an internal stock of rich tacit knowledge and reduce dependence on external partners during the early development phase. Embedding knowledge in a product could also yield more economic returns in the long run. It can further be assumed that external partners neither possessed the needed knowledge nor shared the same passion for the project. Toyota wanted to create an internal *ba* for the project and utilize external networked knowledge later, when smoothing the manufacturing processes and cutting down costs.

The origins of the Prius project

The origin of the Prius project can be traced back to initiatives made by a small study group that executive vice-president of R&D, Mr Yoshiro Kimbara, started in order to find alternative ways to increase future competitiveness in late 1993. The initiative had strong top-management support from the beginning. The general manager of the General Engineering Division, Mr Ritsuke Kuboshi, was soon selected to take over as leader of the initiative. He was formerly the chief engineer of Celica, with a reputation for being aggressive and strongly determined. Mr Kuboshi used his network to select ten middle managers for a small study group later called Generation 21st Century (G21). They met once a week, on top of their daily work, to study the vehicle for the 21st century. As an indication of the vision and urgency, it was decided that the final output of the project should be a mass-produced, mass-marketed, fuel-efficient vehicle. Another mission was to search for a new way to do product development. They had only three months to complete the mission.

The high-level sponsorship increased commitment and urgency to create as comprehensive a plan as possible within the limited time period. As a guideline, they had only the implicit understanding that Toyota was seeking to move to the next level in automobile development. The fact that they were able to develop structured guidelines and a half-size blueprint indicates the level of commitment among employees. Toyota frequently uses projects to test the aptitude of potential hand-picked future managers. One such team member was Mr Sateshi Ogiso, who stayed with the hybrid car project until its launch in 1997. Although Mr Ogiso was only 32 years old, Mr Kuboshi gave him demanding responsibilities to cultivate his leadership skills. He was also made responsible for preparing the final report to the Toyota Motor Company Board.

The G21 group proposed to the Toyota Motor Company Board that the new vehicle should:

- realize a larger inner space by making the wheel base as long as possible;
- place the seats at a higher position to make it easier to get in and out of the car;
- make the car more aerodynamic by making the body height about 1,500 mm;
- improve fuel efficiency by 50 per cent in comparison to the vehicles in the same class (the target was 20 km per liter);
- use a small engine and efficient automatic transmission.

The reference vehicle for fuel efficiency was the Toyota Corolla. The report did not make any specific proposal to develop a hybrid car, partly because the development at that time was considered embryonic for mass production. Further, the G21 group was at this stage still largely influenced by the dominant paradigms of vehicle development. The next step was to develop a more detailed blueprint for the vehicle.

Hybrid vehicle development

Mr Takeshi Uchiyamada was selected to lead the second stage of the G21 project, in January 1994. The project mission was to create a global small car for the 21st century. Before the assignment, he was a test engineer, in charge of reorganizing R&D laboratories. These responsibilities made him knowledgeable about Toyota technologies, and able to locate people with the needed knowledge. Although a novice at leading a new-model development project, his technical knowledge, social networks, and relative inexperience were considered to be beneficial in developing a concept-breaking vehicle: the inexperience allowed him to evaluate critically and, if necessary, to break the established product-development routines and dominant thinking. And his social networks enabled him to locate the right people with the right knowledge.

The G21 project deviated in many respects from ordinary product-development projects at Toyota. The goal to develop a concept-breaking vehicle meant there was virtually no interaction with external parties. Attention to internal resources increased focus, commitment, and full utilization of knowledge resources. And the strong top-management support gave the team relatively free access to resources. According to Mr Uchiyamada, he was 'given a free hand, unbound by any of the usual corporate and engineering constraints; freedom from component sharing and commonalities, marketing considerations, and product hierarchy.' Moreover, the core members were solely dedicated to developing one end product. This enabled Mr Uchiyamada to focus on one task and build a self-sufficient team with all necessary capabilities. The carefully selected initial ten members with about ten years of experience came from eight technological areas, among them body, chassis, engine, drive system, and production technology. They were all in their in their early thirties—old enough to have expertise, but young enough to be flexible.

Having a core team working solely for one product enabled the sharing of physical space. It was the first time at Toyota that a whole product-development project team had worked in one room. They installed two CAD systems and PCs in the room. The concentration of people increased commitment, knowledge exchange, and decision-making speed. In addition, the knowledge diversity and inter-functional interaction enabled team members to develop an overview of the whole project and the various challenges involved in real time. The experiences during the project were carefully documented and, after the hybrid vehicle project, sharing one big room in new-product development became a common practice at Toyota, because of the efficiency of knowledge combination.

Mr Uchiyamada was quick to identify factors that might slow the project down. He sought to increase commitment, interaction, and decision-making with such credos as:

- technology should be evaluated by everyone, regardless of specialty;
- one should think what is best for the product instead of representing one's own department's interests;
- one should not care about age or rank when discussing technologies.

These guidelines aimed to break down structural rigidities and promote openness for constructive criticism, finding solutions through cross-functional collaboration, and open sharing of ideas. He emphasized delaying final decisions in order to perceive problems from various angles, especially in the development of physical prototypes.

At the beginning of the project, the team followed the earlier guidelines for developing the twenty-first-century vehicle. The group envisioned a small sedan with seating for four adults that would focus on safety, looks, low pollution, and efficiency. A 1.3- or 1.5-liter direct injection engine was thought to be the answer for improved fuel efficiency. Top management rejected this first proposal due to its conventionality; the guidelines were consequently respecified to force the team to seek radical solutions beyond the existing technological boundaries, and, critically, top management made a decision to break organizational silos and forge creative linkages among various *ba*. It was for this reason that Executive Vice-President Wada established an idealistic goal of 100 per cent improvement in fuel efficiency. It was also emphasized that the goal of the project was a mass-produced vehicle.

The team set about the changes required by this rejection of a conventional engine in favor of the underdeveloped hybrid system. The first goal was to develop a concept car for the 1995 Tokyo Motor Show in late October—the team had about one year. The concept car was named Prius, the Latin word for 'before.' At that time, the leaders of the two projects—G21 and hybrid development—were separated in terms of goals and understanding. Initial interactions between the groups revealed problems in the fuel infrastructure: constant battery recharging was required in the hybrid technology. Toyota had developed the hybrid system at the Electronic Vehicle Department, but the now-urgent need to create a synergist hybrid technology for mass production meant there was also a need to build a bridge between technology development and manufacturing. To develop the production technologies for the hybrid system, Toyota created the Unit Production Technology Department.

In order to increase concentration and development speed, Mr Wada formed a project team to research and to analyze candidate hybrid technology for mass-produced vehicles. Because of the relatively long in-house experimentation, the team had many choices. According to Mr Uchiyamada: 'We had 80 research engineers and we got over 80 plans, including historical ones and those in the heads of our researchers.' Those eighty were first narrowed down by a newly developed analytical program to twenty, and then finally to four technologies. Each of these four was evaluated carefully through computer simulation. At the engineer management meeting, the final choice was made, based on efficiency, cost, and business advantage. The approved technology was code-named 890T in mid-June 1995.

This hybrid system was still largely in the research phase, and the head of the hybrid project, Mr Takehisa Yaegashi, and his team of fifteen engineers worked day and night to build an engine for the concept car. They completed one in time for the Tokyo Motor Show. The concept car aroused wide interest at the motor show, but it was not ready for mass production. After the Motor Show, the Product Audit room, responsible for evaluating a car from the viewpoint of users, tested the car designed for mass production at the test course. On the first day, the car did not start. On the subsequent try, it moved only one meter. For fifty days, because of a basic engineering fault which caused logistical problems, the prototype Prius was not drivable: the engine and motor computers failed to communicate with each other. It finally moved about 100 meters under its own ICE/electric power in December 1995. Said Mr Uchiyamada, 'At that time, my first impression was "It moves!" rather than "It runs." '

The small event was one of the reasons that top management changed the target time for market introduction. The vehicle had originally been planned to be ready for the market at the end of 1999, which was a very short time period for designing, developing, and getting manufacturing ready for a complex product. It usually took an average of approximately four years for Toyota to develop a car; the ambitious goal for the Prius and its new technologies was fifteen months. However, when Mr Wada introduced a new plan for launch in 1998, the President, Mr Hiroshi Okuda, said, 'It is too late. Could it be one year earlier? It is important that we release it early. This car may change the future of the auto industry, not to mention the future of Toyota.' The Chairman, Mr Shoichiro Toyoda, and President Okuda insisted on the early launch in December 1997: another reason for it, according to Mr Uchiyamada, was the Kyoto Conference on global warming issues in 1997.

The change in market-introduction target time forced the team to find ways to cut the product-development cycle time. The challenge was to control the technological uncertainty, stimulate creative problem solving, and make sure that the time limits were not exceeded. Mr Uchiyamada decided to coordinate the whole project with three experienced members. One member was responsible for the hybrid system, another for the body, cost issues, and weight, with the remaining member responsible for regulatory issues, production planning, and marketing. Mr Uchiyamada explained, 'You have to keep the numbers down if you want to develop a vehicle quickly.' The intent was also to set parameters early and make key decisions as quickly as possible. The other key decision was to rely on extensive simultaneous engineering, which brought various groups together in product development. As the hybrid system was still in the research stage, both the research and the development were conducted at the same time.

Horizontal and cross-functional cooperation was critical in order to create a mutual understanding of the diverse technologies and the dependencies among them. In contrast with previous projects in which development teams submitted 'orders' to related departments to develop necessary components for new models, cross-functional cooperation during the hybrid project was intense and spontaneous. In addition, engineers had to possess and develop knowledge beyond their specialties due to the complex technological interrelations in the hybrid system. The efficiency of the hybrid system depends on the combination of all subsystems, and when problems occurred in the integrated system, engineers had to find the cause of the problem in close cooperation. All these functions sought to fulfill the vision of the criticality of speed.

The G21 was made an official product-development project and was renamed 'Product Planning Zi' in January 1996. In addition to the core members from G21, Mr Toshihiro Ohi joined Zi to oversee the entire process of commercialization, production technology, production, sales, and public relations. He was another heavyweight leader that was brought in at the right time to speed up the product launch. In addition to wide networks, he brought vital knowledge that was needed to commercialize the vehicle based on customer needs. Unlike other members, he had fifteen years of experience in product planning and commercialization for cars such as Tercel, Starlet, Corsa, and Sainos. Furthermore, because of the top priority of the project, Mr Uchiyamada was able to obtain the needed human resources. About 1,000 people eventually worked for the project at Toyota (most of them on a part-time basis).

In addition to the hybrid technology, the aerodynamics, maximum interior space, and ergonomics were all important to the vehicle's development. The small vehicle should be large enough inside to contain the hybrid technology and be comfortable to passengers. The vehicle was virtually built around passengers, as Mr Uchiyamada described:

> I placed the driver not in a hypothetical automotive package, but in a comfortable seated posture mid-air. The front-seat passenger, likewise, was in a comfortable position with the right amount of space between him or her and the driver. Rear-seat passengers followed. And around the four floating people a package was created, with small outer dimensions and optimum interior space.

A competition was held to increase diversity in vehicle design in February 1996. The participants were from design centers in California, Europe, Tokyo, and Toyota City. Seven teams presented more than twenty designs. Five of them were chosen for further evaluation, with two reaching the final competition. They were from the Design Department at the Toyota headquarters and Calty Design Studio in California. The headquarters design was an extension of the existing models. In contrast, the Calty design was futuristic. The panel of judges consisted of Toyota executives and 100 employees. While the executives appreciated both designs, employees favored the futuristic design, and the winner was Calty's Mr Irwin Lui. The first-generation Prius was short and upright, distinctive among contemporary small sedans.

Battery joint venture

While most problems were eventually solved during the project, the persistent obstacle was battery technology. Because of the limited car size, the batteries needed to be small, but powerful enough for smooth functioning. They should also be reasonably priced and have a long life-cycle. Toyota did not have the in-house knowledge to tackle the problems involved, and formed a joint venture with Matsushita Battery Industrial Co. Ltd. (MBI) in December 1996. MBI was a logical partner: it had knowledge of developing batteries for electric-powered vehicles. The Electronic Vehicle Development Department had also cooperated earlier with MBI to develop a nickel hydrogen battery for RAV-4. In the joint venture, called Panasonic EV Energy Co. Ltd., the role for MBI was to produce battery cells, and Toyota's was to produce modules and holders.

The external cooperation brought with it the problems of developing the *ba* for smooth interaction. The early challenges in joint development and production were heat resistance and quality control. Because batteries were initially placed next to the engine, heat created problems. The early battery prototypes were heat sensitive and could not be used on hot days. The other challenge was to create a shared mindset on quality control: while MBI tolerated certain failure rates, tight quality control was required for hybrid car technology. Because of the early production problems, the first batteries produced less than one-third of the required performance.

The shared mindset came through movement of management-level employees, open dialogues, and shared understanding of the requirements needed for a mass-produced vehicle. When test drives took place in July and August 1997 in extreme conditions in Japan, Nevada, California, and New Zealand, engineers of Panasonic EV Energy participated to understand battery requirements in real conditions. These experiences in the actual context enabled engineers to detect problems quickly, and several modifications were made in the following months to prevent battery failures.

Product launch

The first media test-drive event was held at the Higashi-Fuji Proving Grounds, and the Prius was unveiled officially to the press in October 1997. The first Prius rolled out from the factory in December 1997. The world's first commercialized hybrid car was welcomed with wonder and surprise, and Toyota had to give three press conferences in Tokyo. The extensive media coverage, reasonable price, and general interest in hybrid technology resulted in a back-order of 3,500 hybrid vehicles, and the company quickly decided to raise production from 1,000 units to 2,000 units per month. The Prius received numerous awards, including Japanese Car of the Year and American Car of the Year, for its innovative product concept and technologies.

The in-house design and production proved to be beneficial for three reasons. First, it enabled the accumulation of knowledge, techniques, and skills: the first Prius included more than 300 patents. Because of the knowledge concentration, Toyota was able to develop and modify the hybrid system in a short time. According to Mr Takehisa Yaegashi, 'I hesitate to say we are much ahead of the others, but I do want to emphasize the difference between Toyota and the other companies ... We have a six-year advantage in mass-producing hybrid cars.' At the time of the launch of the first Prius, Toyota's closest rival, Honda, was estimated to be about three to four years behind Toyota in the late 1990s. Second, the company has been able to improve and simplify technology to reduce costs. According to Mr Inoue, 'We have been able to significantly reduce the cost of major hybrid components and sophisticated support systems through in-house R&D.' Third, Toyota has been able to use the created knowledge across all main developmental drives: alternative energy, such as compressed natural gas; diesel engines; gasoline engines; and electronic vehicles.

Second-generation Prius

At the New York Auto Show in 2003, the second-generation Prius demonstrated how quickly Toyota was able to make improvements in hybrid technology. In addition to increased attention to exterior design, the new model is based on a new main system called Toyota Hybrid System II (THS II), which has moved the hybrid technology to a new level. According to Mr Satoshi Ogiso, who had been with the Prius project from the beginning:

> For the second-generation Prius, we focused on the promotion of widespread use and driving performance. No matter how good the environmental performance, if the system does not come into wide use, its benefits will not be felt by society. We completely abandoned the original concept of the Prius and started with a blank slate to create a new concept. Our biggest concern was whether we would be able to create a second-generation vehicle that could compare to the epoch-making first generation.

Despite only having a 1.5-liter engine, the hybrid system enables the new Prius to have acceleration that outpaces 2.0-liter-engine cars. The main focus in the development was placed on the high-voltage circuit between the battery and the generator, which increases the voltage to the motor provided by the battery. The battery still provides 21 kW, but it is smaller and less costly to produce than in the previous model.

When the second-generation Prius reached US showrooms in October 2003, dealers received 10,000 orders before the car was even available. The environmental performance of the new Prius has been praised in Europe, and it is subject to preferential tax treatment in fifteen countries, including France, the United Kingdom, and Germany. The new Prius has received several awards, such as 'Car of the Year' from the US magazine *Motor Trend*, 'Best Engineered Vehicle' from the Society of American Automotive Engineers, 'North American Car of the Year' from the US automotive journalists, and 'International Engine of the Year 2004' from international automotive journalists. In addition, support from users shows the extent to which Toyota has succeeded in raising consumer appreciation of hybrid vehicles.

Toyota is seeking to utilize hybrid technology in a wide range of vehicles. In the process, the horizontal deployment (*yoko-ten*) of ideas and technologies is being used extensively. The company has announced that, by summer 2005, it will start to sell a hybrid Lexus SUV, RX400h, whose V6 engine will deliver power rivaling that of a V8 engine, with the fuel efficiency of a compact car. The hybrid technology will be likely to be extended further to diesel engines in trucks and commercial vehicles.

Toyota is offering its technology to other automakers to create scale economies. Executive Vice President Akihiko Saito explains:

> We believe that the proliferation of environmental technologies is essential. Proliferation is not something that Toyota can achieve on its own, and when considering the global environment, it is important that automakers from around the world work together. That is why we are considering disclosing technologies.

This has so far led to the signing of licensing agreements with Nissan and Ford. Several Japanese carmakers have launched a hybrid vehicle, or are seeking to launch one in the near future. The success of hybrid vehicles has not gone unnoticed in Europe, where several makers have announced market launches in 2003 and 2004. The patent activity on hybrid technology has accordingly increased rapidly in recent years. While most American carmakers have been skeptical about developing hybrid vehicles, General Motors announced in December 2002 that it plans to sell one million hybrid vehicles by 2010. The others are likely to follow.

Discussion

The flow of occurrences leading to the first commercialized hybrid vehicle evolved from policy statements and environmental concerns. While most automakers were hesitant to develop environmentally friendly technologies, the Toyota Motor Company Board had an idealistic vision to develop a twenty-first-century vehicle and product-development processes. This vision led to a creation of a small study team of ten middle managers in late 1993. Increased commitment brought in managers with wide experience and networks, and the new product-development project eventually tied together about 1,000 employees from various organizational layers in 1997. Important in the process was the right mix of people and selective top-management promotion of interaction and direction.

The G21 group responded to the ambitious goals by redefining processes and combining various knowledge domains, which enabled the fast organic growth from early policies to a mass-produced hybrid vehicle (Figure 4.2).

For example, the goal of 100 per cent improvement in fuel efficiency provided the needed push at the right time to break away from the dominant thinking in order to search for radical solutions; it also enabled the rewiring of two dense, separated *ba* at Toyota and overcame silo barriers and human defense mechanisms. In order to promote urgency and direction, top management further began to emphasize that the future of the company largely depended on the completion and success of this single project. Project leaders conveyed this urgency to various *ba* by continually repeating and emphasizing the primacy of that underlying purpose. Experts with relevant knowledge and connections were included as the project evolved.

Efficient knowledge-creation processes within *ba* and among *ba* enabled the development of various subjective ideas into a concrete product. For example, Mr Uchiyamada visited research and development departments at the early stages of the project to create overall understanding of core technology and select the right people with relatively long experience. Desired competencies for team members were flexibility and deep understand-

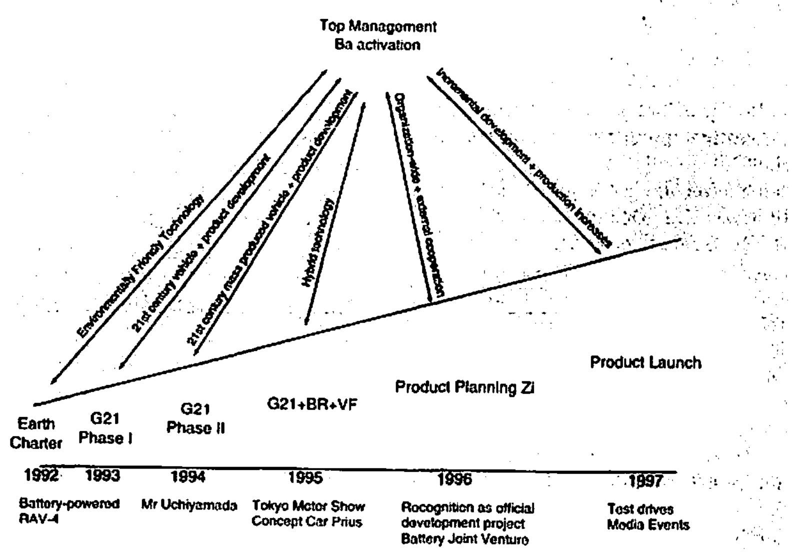

Fig. 4.2. Hybrid vehicle project evolution

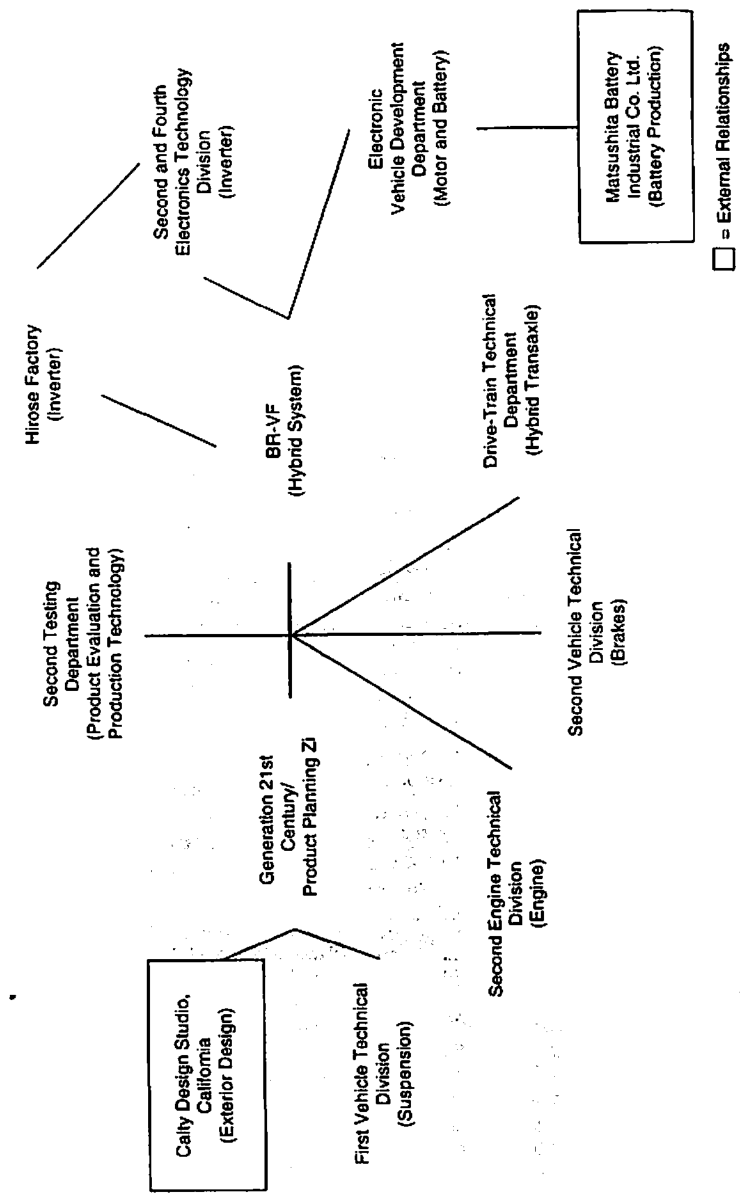

Fig. 4.3. Various *ba* at the Toyota Prius project

ing of interrelated technologies. This enabled fast and efficient knowledge exchange. The team members were quick to create the key concepts for the twenty-first-century vehicle, and ready to change their mindsets when their initial plan was rejected. Team members used information technology and visited other teams to share their embryonic concepts and ideas with relevant entities to get creative criticism and diverse ideas for improvements. They further documented their experiences in a 200-page book that has been used since to develop research and development processes at Toyota.

The urgency, the focus on a single product, and the strong top-management support enabled the core team to utilize various organizational resources quickly and efficiently, and to link various *ba* into a self-transcending and coherent fashion tied by a single overarching vision (Figure 4.3). The seemingly risky, but calculated, top-management goal was to create strong linkages and shared visions between the G21 group and the BR-VF hybrid system. While various *ba* were unified by a single vision, they were given autonomy to reach targets by self-organizing action. In addition, somewhat free utilization of organizational resources, the concentration on one product, and close cross-functional interaction enabled people and teams to bring their own experiences and contexts into *ba* to make the shared context a rich one.

In summary, the case shows that knowledge creation needs many, multi-level *ba*, connected to each other organically to form a greater *ba*. An organization is an organic configuration of *ba* in motion, where various *ba* form a fractal. Hence, leaders have to facilitate the differentiation and interweaving among a variety of seemingly distant and disconnected *ba*, and to synthesize the knowledge that emerges from the larger *ba*. An important enabler in the process was the accumulated tacit knowledge that was carefully connected and rewired from various organizational domains.

Conclusion

This chapter presents, through case analysis, a knowledge-based view of radical innovation. Instead of viewing innovation merely as a 'final' state, we describe innovation as a creative process. The knowledge-creating theory describes the process through the SECI and *ba*, in which subjective but rational human actors combine tacit and explicit knowledge in dialectic fashion. The context and processes are combined by vague and inspirational knowledge visions, which middle managers execute through intense social interaction. Their human connections enable them to link various *ba* as a large and systematic knowledge-creating system. While external networks enable firms to detect market possibilities, early phases of radical innovation are, provided that appropriate knowledge domains exist, conducted most efficiently within companies.

The development of the Prius was radical in at least three respects. First, it did not fit into any existing product line and it was designed to give Toyota a new image. Second, the vehicle used innovative technologies in its engine, motor, battery, and brakes, and in combining them into a hybrid system. Many of these new technologies were later applied to other products. Third, Toyota used a new method of product development to produce the Prius. While it usually took about four years for Toyota to develop a new model of an existing product, the Prius was developed in fifteen months. The increased speed in product development enabled Toyota to expand lines more rapidly and renew products more quickly. An interesting detail was the relative lack of external involvement in the product-development process.

A case study was used in this chapter to illustrate social processes leading to radical innovation in one company. While Toyota is a distinctive company with its own culture, practices, and history, case studies on radical

innovation projects show that strong top-management vision and support, linkage of knowledge resources by middle managers, and strong knowledge fermentation, enable radical innovations, especially in Japanese organizations (Nonaka and Takeuchi 1995; Nonaka *et al.* forthcoming). In order to identify the mechanisms and differences between companies in radical innovation processes, future research could be conducted using both qualitative and quantitative methodologies for depth and breadth in understanding the phenomenon of radical innovation.

Note

1. The case is based partly on an unpublished work by Ryoko Toyama.

References

Alvesson, M. (1996). *Communication, Power and Organization*. Berlin: Walter de Gruyter.

Anderson, P., and Tushman, M. L. (1990). 'Technological Discontinuities and Dominant Designs: A Cyclical Model of Technological Change.' *Administrative Science Quarterly*, 35: 604–33.

Barbasi, A. (2002). *Linked: The New Science of Networks*. New York: Perseus Publishing.

Barney, J. (1991). 'Firm Resources and Sustained Competitive Advantage.' *Journal of Management Studies*, 17/1: 99–120.

Bohm, D. (1990). *David Bohm: On Dialogue*. David Bohm Seminars, Ojia.

Bourdieu, P. (1985). 'The Genesis of the Concepts of "Habitus" and "Field".' *Sociocriticism*, 1/2: 11–24.

Brown, R. H. (1978). 'Bureaucracy as Praxis: Toward a Political Phenomenology of Formal Organizations.' *Administrative Science Quarterly*, 23: 365–82.

Chia, R. (2003). 'From Knowledge-Creation to the Perfecting of Action: Tao, Basho and Pure Experience as the Ultimate Ground of Knowing.' *Human Relations*, 56/8: 953–81.

—— (2004). 'Strategy-as-Practice: Reflections on the Research Agenda.' *European Management Review*, 1: 29–34.

Damanpour, F. (1991). 'Organizational Innovation: A Meta-Analysis of Effects of Determinants and Moderators.' *Academy of Management Journal*, 34/3: 555–90.

Dyer, J. H., and Nobeoka, K. (2000). 'Creating and Managing a High-Performance Knowledge-Sharing Network: The Toyota Case.' *Strategic Management Journal*, 21: 345–67.

Giddens, A. (1984). *The Constitution of Society*. Berkeley: University of California Press.

Hage, J. (1999). *Organizational Innovation (History of Management Thought)*. Dartmouth: Dartmouth Publishing Company.

—— and Hollingsworth, J. R. (2000). 'A Strategy for the Analysis of Idea Innovation Networks and Institutions.' *Organization Studies*, 21: 971–1004.

Hayek, F. A. (1948). *Individualism and Economic Order*. London: Routledge and Kegan Paul, Ltd.

Heidegger, M. (1962). *Being and Time*. New York: Harper and Row.

Husserl, E. (1931). *Ideas: General Introduction to Pure Phenomenology*. New York: Macmillan.

—— (1947). *Erfahrung und Urteil: Untersuchungen zur Genealogie der Logik*. Hamburg: Claassen and Goverts. (Eng. trans., *Experience and Judgment* by J. S. Churchill and K. Ameriks. London: Routledge and Kegan Paul, 1973.)

Lawson, T. (1997). *Economics and Reality*. New York: Routledge.

Merleau-Ponty, M. (1962). *Phenomenology of Perception*. London: Routledge.

Nishida, K. (1970). *Fundamental Problems in Philosophy: The World of Action, the Dialectical World*. Tokyo: Sophia University.

Nonaka, I. (1991). 'The Knowledge Creating Company.' *Harvard Business Review*, 69: 96–104.
—— (1994). 'A Dynamic Theory of Organizational Knowledge Creation.' *Organization Science*, 5/1: 14–37.
—— and Konno, N. (1998). 'The Concept of 'BA': Building a Foundation for Knowledge Creation.' *California Management Review*, 40/3: 40–54.
—— and Takeuchi, H. (1995). *The Knowledge-Creating Company*. New York: Oxford University Press.
—— and Toyama, R. (2003). 'The Knowledge-Creating Theory Revisited: Knowledge Creation as a Synthesizing Process.' *Knowledge Management Research and Practice*, 1/1: 2–10.
—— (2002). 'Firm as a Dialectic Being: Towards the Dynamic Theory of the Firm.' *Industrial and Corporate Change*, 11: 995–1019.
—— Peltokorpi, V., and Tomae, H. (forthcoming). 'Strategic Knowledge Creation: The Case of Hamamatsu Photonics.' *International Technology Management Journal*.
—— Toyama, R., and Konno, N. (2000*a*). 'SECI, *Ba* and Leadership: A Unified Model of Dynamic Knowledge Creation.' *Long Range Planning*, 33/1: 5–34.
—— —— and Nagata, A. (2000*b*). 'A Firm as a Knowledge Creating Entity: A New Perspective of the Theory of the Firm.' *Industrial and Corporate Change*, 9/1: 1–20.
Peltokorpi, V. (2004). 'Transactive Memory Directories in Small Work Units.' *Personnel Review*, 33/4: 446–67.
Pettigrew, A. M. (1977). 'Strategy Formulation as a Political Process.' *International Studies of Management and Organization*, 7: 78–97.
Polanyi, M. (1952). *Personal Knowledge*. Chicago: University of Chicago Press.
Rescher, N. (1987). *Ethical Idealism: An Inquiry into the Nature and Function of Ideals*. Berkeley: University of California Press.
—— (2003). *Epistemology: On the Scope and Limits of Knowledge*. Albany, NY: State University of New York Press.
Schön, D. A. (1983). *The Reflective Practitioner*. New York: Basic Books.
Schumpeter, J. A. (1934). *Theory of Economic Development*. trans. R. Opie, Cambridge, MA: Harvard University Press.
Schutz, A. (1932). *The Phenomenology of the Social World*. Evanston, Ill.: Northwestern University Press.
Searle, J. R. (1983). *Intentionality: An Essay in the Philosophy of Mind*. New York: Cambridge University Press.
Thompson, J. (1967). *Organizations in Action*. New York: McGraw Hill.
Tsoukas, H. (1996). 'The Firm as a Distributed Knowledge System: A Constructionist Approach.' *Strategic Management Journal*, 17, Winter Special Issue: 11–25.
Van de Ven, A. H., Angle, H. L., and Poole, M. S. (1999). *Research on the Management of Innovation: The Minnesota Studies*. New York: Oxford University Press.
Varela, F., and Shear, J. (1999). 'First-Person Accounts: Why, What, and How.' In F. Varela and J. Shear (eds.), *The View from Within: First Person Approaches to the Study of Consciousness*. Thorverton: Imprint Academic.
Von Hippel, E. A. (1988). *The Sources of Innovation*. Oxford: Oxford University Press.
Watts, D. J. (2003). *Six Degrees: The Science of a Connected Age*. New York: Norton.

5 Innovation, Competition, and Enterprise: Foundations for Economic Evolution in Learning Economies

J. Stanley Metcalfe

Introduction

This chapter reviews a triad of related ideas at the core of how an understanding of the connections between the growth of human capability and the growth of material standards of living are related. It outlines a framework in which this triad—innovation, enterprise, competition—and the development and growth of an economy are woven together in a fabric of change. The framework defines the restless nature of modern capitalism, its incessant capacity to transform itself from within in a continuous process of creative destruction. Capitalism can never be stationary. Its dynamic and transformative powers have marked effects across time and space. The chapter explores the foundations of this perspective; it justifies the label of 'restless' for the attributes of this economic system; it traces the consequences for the development of that economy and its connection with the continued growth in standards of living.

The metaphor of restlessness suggests a search for improvement and a sense of discomfort and uncertainty about how the economic order and the position of individuals within it will evolve. Foremost among these attributes are the connection between the triad and the growth of knowledge, the evolutionary nature of a competitive process grounded in innovative rivalry, and the complementary role of market and non-market processes in shaping innovation and the economic response to innovation. Among these non-market processes are those defined by innovation systems. As we witness at every level of aggregation in any modern economy, the institutional framework of modern capitalism is unique in its self-organization and self-transformation of economic activities. In short, a modern economy is incessantly evolving into a new economy; there is always an edge of modernity to the system so that, over extended periods of time, continuity can only be found in process and broad institutional form, not in morphology and activity. What is significant about the current phase of capitalism is that this process is spreading: an increasing number of economies are taking on the attributes of restless capitalism. China and India are leading examples, following the successes of S. Korea and the other 'tiger economies;' they will no doubt be followed by others on the edge of modernity, such as Brazil, or the transition economies of the former Soviet bloc (Amsden 1989, 2001). The emergence of new capitalisms can only accelerate change in the established Western economies, which will have to find new sources of comparative advantage to sustain their relatively high standards of living. That is to say, an innovative response will be required to the challenge of new international competition. But to say this is simply to