Technology and High Technology: Support Net and Barriers to Innovation

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BIOGRAPHICAL NOTES

After a decade at Columbia Business School in New York, he joined Fordham University at Lincoln Center as a Professor of Management Systems. His current appointments include many locations throughout the world in USA, China, also in Czech Republic. He is now the principal of the emerging Entrepreneurial University: a network of international, private, complementary and synergy enhancing institutions producing not only the graduates but also the firms they have established and operated.

KEY WORDS

Technology, high technology, support net, technology management, hardware, software, brainware, innovation, innovation process.

ABSTRACT

Technology support net (or "infrastructure"), when fully established and fixed, presents significant barriers to technological innovation. Innovation is no longer autonomous, but technically and politically subservient to the "holders and owners" of the support net. We present new, operational definitions of technology and high technology which allow effective technology management and explain past and current barriers to shifting from one technological paradigm to another. As an example, the one-hundred years old fixation on internal combustion engine, oil and gas, etc. can be traced to technology support net and its constraints. Technology is not just hardware, but also software and brainware, and primarily the requisite support net which fixates, limits and predetermines the flows and types of innovation.

1. Introduction

Current era is characterized by highly predetermined flows of innovation. For more than a hundred years it has become virtually impossible to step out of scientific paradigms of internal combustion engine, general burning of fossil fuels and all energy dependent technologies. Even now, when the needs for environmental protection have become blatantly obvious and economies based on combustion and burning are being strangled with costs, performance and ecological impact, new technologies are evolving very slowly, struggling against technical, political and social status quo.

It is the technology support net (or "infrastructure") which - when fully established and fixed - presents significant barriers to qualitative (paradigmatic) rather than quantitative innovation. The process of innovation is no longer free and autonomous, but rather technically and politically subservient to the "holders and owners" of the support net.

In this paper we present operational definitions of technology and high technology, which would allow effective technology management and explain past and current barriers to shifting from one technological paradigm to another. As an example, we use the one-hundred years old fixation on internal combustion engine, oil and gas, etc., which can be traced to its technology support net and corresponding constraints.

Technology is not simply hardware, but also software and brainware – and, primarily, the requisite support net which fixates, limits and predetermines the flows and types of innovation.

The implications of this view are very significant: processes of invention and innovation are not limited by lack of knowledge or too narrow business criteria, but by the existing supporting infrastructure. Such understanding calls for a different emphasis and direction of business and engineering innovation efforts. The focus is not so much on hardware (which is becoming commoditized), nor software or brainware, but on the boundaries and architecture of the support net itself. This calls for a new paradigm of technology management, design and applications.

2. Challenges to Technology Management

The nature of technology has changed in the global era: it is becoming more integrative and more knowledge-oriented, it is available all around the globe and it includes also logical schemes, procedures and software, not just tools and machinery. It tends to complement or extend the user, not to make him a simple appendage. The notion of technology has to be redefined: it should be viewed as a form of social relationship, with hardware and software being enabled by brainware and technology support infrastructure.

Let us start by recalling the views of Stiglitz (1999) on technology transfer: "History teaches us that transferring hardware is insufficient and ineffective. Codified technical information assumes a whole background of contextual knowledge and practices that might be very incomplete in a developing country. Implementing a new technology in a rather different environment is itself a creative act, not just a copied behavior. Getting a complex technical system to function near its norms and repairing it when it malfunctions are activities drawing upon a slowly accumulated reservoir of tacit knowledge that cannot be easily transferred or 'downloaded' to a developing country."

The emphasis is on the insufficiency of information (or codified "knowledge") and the hardware-software mindset. Information can always be "downloaded," knowledge cannot. Knowledge has to be produced within the local circumstances and structural support.

Technology has been one of the main engines of economic development since the Industrial Revolution. Yet, its operational definition has been neglected and most people know it either from macroeconomics simply as "T" (in some arcane formula) or through a listing of hardware or "machinery" (like drill, computer, robot or crane). Such levels of treatment are clearly inadequate in the era of High Technology – i.e. forms of technology that increasingly have to be managed by managers and customers, not simply designed by engineers. The managerial perspective on technology has been so far missing.

3. Technology: definition, forms and functions

At its most fundamental, technology is a tool used in transforming inputs into products or, more generally, towards achieving purposes or goals. For example, the inputs can be material, information or services. The product can be goods, services or information. Such a tool can be both physical (machine, computer) and logical (methodology, technique). Technology as a tool does not have to be from steel, wood or silica, it could also be a recipe, process or algorithm. In order to utilize technology efficiently and effectively, we must grasp its broader definition and its broader embedding in the requisite enabling infrastructure.

Technology is a package of hardware, software, brainware and the support net. In many modern technologies, the hardware is becoming a commodity, the least decisive component, a mere physical casing for the real power of effective knowledge contents. The enabling infrastructure, or technology support network, is often becoming the most important component of technology: in the near future it will not be the number of computers per capita, but the density and capacity of their network interconnectedness which will determine their effective usage.

It's not what you use or how you use it, but what you use it for and why. The shift from "what and how" to "what for and why" is virtually a defining factor of the high technology. It is the high technology that is characterized not by the change in hardware or software, but by the requisite change in the enabling infrastructure: it requires doing things differently and doing different things, not merely doing the same things better or more efficiently.

3.1 Components of Technology

Any technology can be divided into several clearly identifiable components:

1. Hardware. The physical structure or logical layout, plant or equipment of machine or contrivance. This is the means to carry out required tasks of transformation to achieve purpose or goals. Hardware therefore refers not only to particular physical structure of components, but also to their logical layout.

2. Software. The set of rules, guidelines, and algorithms necessary for using the hardware (program, covenants, standards, rules of usage) to carry out the tasks. This is the know-how – how to carry out tasks to achieve purpose or goals.

3. Brainware. The purpose (objectives and goals), reason and justification for using or deploying the hardware/software in a particular way. This is the know-what and the know-why of technology. That is, the determination of what to use or deploy, when, where and why.

These three components are interdependent and equally important. They form the technology core. Components of the technology core are codeterminant, their relations circular (non-linear and non-hierarchical) and mutually enhancing.

This concept of technology is clearly illustrated when we consider an automobile as technology:

A car consists of its own physical structure and logical layout, its own hardware. Its software consists of operating rules of the push, turn, press, etc., described in manuals or acquired through learning. The brainware is supplied by the driver and includes decisions where to go, when, how fast, which way and why to use a car at all.

One could similarly define computers, satellites or the Internet in terms of these three dimensions. Any information technology or system should also be clearly identifiable through its hardware, software and brainware.

4. High Technology and its Support Net

There is a fourth and the most important aspect of technology: 4. Technology Support Net. The requisite physical, organizational, administrative, and cultural structures: work rules, task rules, requisite skills, work content, standards and measures, styles, culture and organizational patterns.

Any technology core (hardware, software and brainware), in order to function as technology, must be embedded in a supportive network of physical, informational, and socioeconomic relationships which enable and support the proper use and functioning of a given technology. We refer to such a structure as the technology support net (TSN).

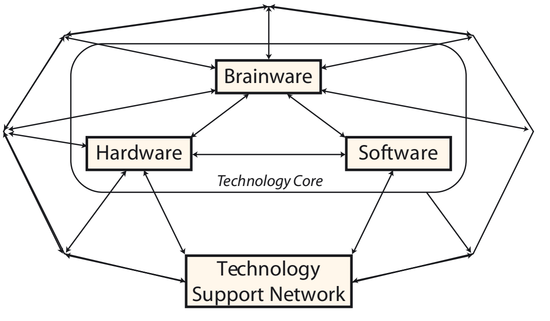

Figure 1. Structure of technology

TSN is a network of flows: materials, information, energies, skills, laws, rules of conduct that circulate to, through and from the network in order to enable the proper functioning of the technology core and the achieving of given purpose or goals.

Ultimately, all the requisite network flows are initiated, maintained and consumed by people participating in the use and support of the use of a given technology. They might similarly and simultaneously participate in supporting many different technologies through many different TSNs.

The entire structure of the technology core and its support network of requisite flows are sketched in Figure 1. It should now be clear that the shape and form of the TSN is the main determinant of technology use.

Every unique technology core gives rise to a specific and requisite TSN and thus to a specific set of relationships among people. Ultimately, the TSN can be traced to and translated into the relationships among human participants: initiators, providers and maintainers of the requisite flows in cooperative social settings.

In this sense, every technology is a form of a social relationship brought forth from the background environment. Only in this sense, and only as such, can it be properly understood, discussed and managed. Let us look at an automobile as technology again. Its TSN consists of an infrastructure of roads, bridges, facilities and traffic signals, but also of maintenance and emergency services, rules and laws of conduct, institutions of their enforcement, style and culture of driving behavior, etc. A large number of people have to be organized in a specific and requisite pattern in order to enable cars to function as technology.

It is clear that technology and its four components can only be defined from the vantage point of the user or observer, not in a context-free or absolute sense. In other words, roads, bridges and traffic signals can be technologies themselves, with their own hardware, software, brainware and support nets.

For example, traffic lights are a part of the TSN of an automobile, but their own hardware can be driven by their own software (a computer-controlled switching program or schedule) and brainware (purposes of safety, volume and flow control, and interaction with pedestrians). This technology core has its own support net of electricity, signal interpretations and car traffic. The traffic light is a technology of its own. Similarly, a piece of software from some technology can itself become viewed as technology (for achieving specific business purposes or goals) with its own hardware, software, brainware and TSN.

Such an observer-dependent definition of technology is also important for identifying important complementary, competing and collaborating technologies through the revealed intermeshing of individual TSNs into larger hyper networks.

4.1 High Technology

The concept of the technology support net allows us to separate the technology core of hard-soft-brainware from its requisite embedding. Different cores can fit the same net, different nets can be tried for the same core, and so on. In this sense, any technology can be characterized as being "misplaced" or "unfit" as well as "right," "fitting" or "appropriate." In the cases of mismatch, both aspects of technology (core and TSN) have to be adapted in order to assure appropriate functioning.

Different changes in the core, both in hardware or software and brainware, will have differentiated effects on the requisite TSN. According to the nature and extent of such changes, we can offer the following definitions:

1. High technology is any technology core that changes the very architecture (structure and organization) of the components of the technology support net. High technology therefore transforms the qualitative nature of tasks of TSN and their relations, as well as their requisite physical, energy and information flows. It also affects the skills required, the roles played, the styles of management and coordination – the organizational culture itself. In short, it allows (and often requires) not only to do things differently but often to do different things. Clearly, high technology should be differentiated from [regular] technology:
2. The technology core affects only the efficiency of flows over the TSN, i.e., it activates quantitative changes over the qualitatively identical architecture of the TSN. It allows users to perform the same tasks in the same way, but faster, more reliably, in larger quantities, or more efficiently, while preserving the qualitative nature of flows and the structure of the support, skills, styles and culture. Technology allows us to do the same thing, in the same way, but more efficiently.
3. The appropriate technology core essentially preserves everything: the support net as well as the flows through it; its effects are neutral with respect to the TSN. It allows users to do the same thing in the same way at comparable levels of efficiency. Improving efficiency is not the purpose here, preserving and protecting the TSN is. Appropriate technology is very important in situations where the stability of the support net is primary for social, political, cultural or environmental reasons.

Introducing the electric typewriter core into the support net of the manual typewriter requires only quantitative changes and adjustments: that is why electric typewriter is just technology. Introducing word processor core in the TSN of the electric (or manual) typewriter requires fundamental changes in net architecture: tasks, inputs, skills and culture. Even the support intermediaries (typists) are mostly eliminated. The word processor clearly enters the classification of high technology.

To summarize our definitions: while technology improves the functioning of a given system with respect to at least one criterion of performance, high technology breaks the direct comparability by changing the system itself, therefore requiring new measures and new assessments of its productivity.

High technology cannot be compared and evaluated with the existing technology purely on the basis of cost, net present value or return on investment: it would be like comparing apples and oranges. Only within an unchanging and relatively stable TSN would such direct financial comparability be meaningful. In other words, you can directly compare a manual typewriter with a better (electric) typewriter, but not a typewriter with a word processor. Therein lays the management challenge of high technology.

Appropriate technology implies that rather than improving the measures of performance, it is the preservation of the TSN itself which is the driving purpose of technology implementation.

The notion of high technology is therefore relative to the vantage point of the technology being replaced. No technology remains fixed and – being a form of social relationship – it evolves. Technology starts, develops, persists, mutates, stagnates and declines – just like living organisms.

There is an evolutionary life-cycle perceived in the use and development of any technology: a new high technology core emerges and challenges existing TSNs which are thus forced to co-evolve with it. New versions of the core are being designed and fitted into an increasingly appropriate TSN, with smaller and smaller high-technology effects. High technology becomes just [regular] technology, with more efficient versions fitting the same support net. Finally, even the efficiency gains diminish, emphasis shifts to product tertiary attributes (appearance, style) and technology becomes TSN-preserving appropriate technology. This technological equilibrium state becomes fixated and stable, resisting to be interrupted by a technological mutation – new high technology appears and the cycle is repeated.

The automobile was high technology with respect to the horse carriage, it however evolved into technology and finally into appropriate technology with a stable, unchanging TSN. Main high-technology advance in the offing is some form of electric car – whether the energy source is the sun, hydrogen, water, air pressure or traditional charging outlet. Electric car preceded the gasoline automobile by many decades and so its return is quite natural in view of comparative costs displacements.

Implementing high technology is often resisted. This resistance is well understood on the part of active participants in the requisite TSN. The electric car will be resisted by gas-station operators in the same way automated teller machines (ATMs) were resisted by bank tellers and automobiles by horsewhip makers. Technology does not qualitatively restructure the TSN and therefore will not be resisted and never has been resisted.

The proverbial "Resistance to change" is not a universal human trait. In fact, humans like change, seek it out and thrive on it – as long as the change preserves the support network they are part of. The electric typewriter, electric tooth brush or the more powerful tractor were never resisted. Technologies and appropriate technologies are not resisted, high technologies are.

Middle management resists business process reengineering because BPR represents a direct assault on the support net (coordinative hierarchy) they thrive on. Teamwork and multi-functionality is resisted by those whose TSN provides the comfort of narrow specialization and command-driven work.

Within the framework introduced here, one cannot fail to observe that modern information- and knowledge-based technologies (including techniques and methodologies) currently tend to be high technologies with high-technology effects. They integrate task, labor and knowledge, transcend classical separation of mental and manual work, enhance systems aspects, and promote self-reliance, self-service, innovation and creativity. The "low" technologies, no matter how new, complex or advanced, are those which still require the dividing and splintering of task, labor and knowledge, increase specialization, promote division and dependency, sustain intermediaries and diminish initiative.

Not all modern or advanced technologies are high technologies: they have to be used as high technologies, function as such, and be embedded in their requisite TSNs. They have to empower the individual because only through the individual can they empower knowledge. It would be hasty to claim that all "information" or "informating" technologies (IT/S) have integrative effects. Some information systems are still designed to "improve" the traditional hierarchy of command and thus preserve and entrench the existing TSN: the administrative model of management. They further aggravate division of


Figure 2

The original Porsche-Electric and modern Eliica

task and labor, further specialize knowledge, separate management from workers and concentrate information and knowledge in centers.

As knowledge surpasses capital, labor and raw materials as the dominant economic resource, technologies are also starting to reflect this shift. Because knowledge is not a "thing," residing in a super-mind, super-book or super-database, but a complex relational pattern of networks brought forth to coordinate human action, technologies are rapidly shifting from centralized hierarchies to distributed networks.

The use of computers provides a good example. The original centralized concept (one computer, many persons) is a knowledge-defying idea of our computing prehistory and its inadequacies and failures have become clearly apparent. The era of personal computing brought powerful computers "on every desk" (one person, one computer). This short and transitional period was necessary for getting used to the new computing environment, but was inadequate from the knowledge-producing vantage point. Adequate knowledge creation and management come mainly from networking and distributed computing: one person, many computers. Each person's computer must form an access to the entire computing landscape or ecology: the Internet of other computers, databases, mainframes, as well as production, distribution and retailing facilities, etc.

For the first time our technology empowers individuals rather than external hierarchies. It transfers influence and power where it optimally belongs: at the loci of the useful knowledge. Knowledge, innovation, spontaneity and self-reliance are becoming increasingly valued and promoted. Hierarchies and bureaucracies do not innovate, free and empowered individuals do.

5. Examples of High Technology

We have used the automobile as an example to demonstrate the importance of the technology support net (TSN) in defining technology and the interactions of its core components: hardware, software and brainware. We have insisted that only a qualitative change in the TNS can bring forth high technology impacts.

Certainly, modern automobile, an appropriate technology of today (albeit with some high technology components and subsystems) is promising to become high technology again, in the near future. The accelerating trends towards gas/electric and electric automobiles, accompanied by the development of hydrogen fuel cells and sun powered batteries, are the harbingers of the high technology transformation of the automobile.

A good example is the recent development that can be referred to as the distributed engine or more popularly as e-Traction. The idea is a century old and comes from the Bohemian designer Dr. Ferdinand Porsche, who did not find the necessary support net for his inventions, either in the internal combustion engine dominated environment, or in his country of origin. In the early 1900s, a 25-year old Porsche of Hofwagen-Fabrik Jakob Lohner & Co. developed electrically powered wheels and used them in roughly 300 different vehicles. In Amsterdam, for instance, both the fire brigade and "Amstel" brewery trucks briefly drove with this distributed type of traction.

Porsche himself had learnt from the Austrian engineer Hans Ledwinka, the father of all-wheel brakes, air-cooled rear engines, articulated headlights and independent rear suspension – and, until 1945, the director of Tatra Kopřivnice. Ledwinka's designs of the Tatra 77, T87 (the famous Tatraplan) and T97 (produced in 1936-1938) were so admired by Hitler that he cajoled Ledwinka into making him detailed drawings – then passed them on to Porsche, outlawed the T97 production in Czechoslovakia - and Porsche's VW Beetle was "born," conceived by Ledwinka, who died in Munich in 1967.

Most gas/electric or electric vehicles today still work through the old-fashioned connecting peripheral wheels to a central motor. A Dutch company "e-Traction" of Apeldoorn has tested a bus in which the motor and wheel form a single unit. Such automobiles can have as many autonomous engines as there are wheels. (For example, see the eight wheels of 1000HP each on Japanese Eliica, in Fig. 2.)

This is not a simple refinement, but a qualitative restructuring of the automobile, promising more miles per charge, better safety, easier maintenance and quiet and clean performance. It has a small combustion engine for charging the batteries, but the main propulsion comes from two electric motors with the tires attached that serve as the rear wheels. Many companies have since tried to popularize the distributed engine, and a few are currently producing them – including WaveCrest Laboratories in Virginia, powering bikes and bicycles. Another innovator is Solectria, a company in Woburn, Mass., that has produced simpler drive trains for more than 100 gas/electric buses.

The e-Traction is however the main player. It has already built a wheel motor for a forklift truck. In mass production, two wheel motors would cost no more than the large engine and other parts that the motors would replace on a regular diesel-powered bus.

The circular shape of e-Traction's motor is not unusual, but the basic parts are reversed. Usually an electric motor consists of a ring-shaped part that does not move, called a stator, through which a current runs, developing magnetic forces that turn the shaft that runs inside it, the rotor. Here, the shaft is fixed and the ring turns. If the shaft was to serve as an axle, and the ring was to have a tire attached, the result would be a motor that serves as a wheel. Such an arrangement would have only one moving part, and would eliminate the parts of the drive train, which transfers power from the engine to the wheels. So, it would eliminate the differential, or gears that allow a vehicle's wheels to turn at slightly different speeds.

Here, speeds are independently controlled. Electric wheels provide a simple way of making a vehicle four-wheel drive. And if one wheel started to slip in acceleration or braking, a central computer could determine that far faster than existing traction control or anti-lock braking systems and make adjustments.

Unlike vehicles with internal combustion engines, most electric vehicles do not need variable transmissions, but they do need a gearbox of some kind. If something went wrong with the motor, with the inverter or with the chips that control the motor, a mechanic could replace them all in about 25 minutes by swapping out the wheel.

Clearly, a new support network of charging, service and maintenance is already emerging. The road and tires would have to be better because the electronics in the motor are in direct contact with the road, not protected like the rest of the bus is by shock absorbers. But the loss of the gearbox is a major benefit. The future of the in-wheel electric engine seems brightening. At the recent Tokyo Motor Show, it was the distributed engine that was the choice in many of the hydrogen-powered concept cars. One hundred years after Porsche.

6. Evolutionary Demands on Technology

An important part of technology support net is a reigning business/management paradigm which dictates the kinds of technology to be most likely accepted and marketed. Business corporations seek technologies which fit and not disrupt their current management systems. One cannot and should not expect certain types of systems to stimulate non-matching, non-fitting kinds of technology. It is therefore important to summarize the evolution of business systems in order to understand their evolutionary demands on technology.

In Fig. 3 we display the basic scheme of the traditional linear input-process-output system. This system has been fixed and unchanging for centuries. The only change has been in terms of changing focus on individual components of the system.

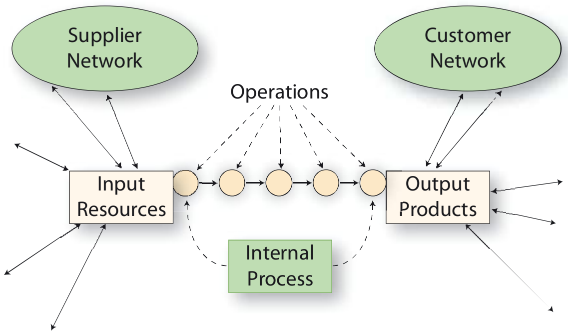

Figure 3. Basic scheme: product, process, external networks

All early evolutionary stages are therefore characterized by changing focus of attention within the essentially unchanging, invariant scheme of Figure 3. The management has sequentially focused on:

1. Final product. The final product is a primary focus, the production process is considered secondary. Its operations and their sequences are technologically fixed or 'given'. Product quality is 'inspected in', mostly at the end of the process. Statistical quality control, inventory control, cost minimization, mass production, assembly lines, work specialization, hierarchies of command, mass consumption, statistical mass markets and forecasting are among the defining characteristics of this stage.

2. Partitioned process. It is the high-quality process that assures the high-quality product. The main focus was on improving of process operations. Quality of the process was understood as the quality of its operations. Powerful new concepts of Total Quality Management (TQM), Continuous Improvement (Kaizen) and Just-In-Time (JIT) systems have characterized this stage. Although the operations were being improved, the process architecture and structural sequencing were kept intact and remained technologically 'given'.

3. Integrated process. The focus of attention shifted from operations (circles) to linkages (arrows) – thus changing the process architecture itself. The reengineering of the process, re-integrating individual components into effective, more autonomous and even self-manageable wholes, has characterized this stage. The production process became a business process and therefore subject to qualitative redesign and reengineering (BPR). Discontinuous improvement and process innovation replaced the piecemeal continuous improvement. Traditional vertical hierarchies of command have flattened out into more horizontal, process-oriented networks. Mass customization, disintermediation, knowledge management and autonomous teams have started emerging.

In all three of the above stages, the corporate focus was rooted in developing the internal sources of competitive advantage, knowledge, innovation and productivity. Only in the next paradigmatic shifts were the internal processes expanded into the extended process – including supplier networks and alliances as well as customer self-service, mass customization and disintermediation – as the main, increasingly external sources of competitive advantage. We have to shift our attention from Figure 3 to Figure 4.

4. Extended process. In this recently peaked stage, networks of suppliers and communities of customers have extended the internal process into a functional and competitive whole. Both internal and external sources of knowledge and competitiveness have formed new core competencies. Supply and demand chains management have emerged, in dependence on shifting CIP (Customer Intervention Point). Intranets and extranets have provided a communication medium for B2B and B2C exchanges. Quality has become bundled together with cost, speed and reliability.

Today, powerful processes of global sourcing bring forth and foster a new set of relationships with customers and suppliers. The firm starts disaggregating its production processes, transferring, leasing or selling selected pieces off to a higher-added value operator or coordinator.

Any firm can be only as good as is the network of which it is a part. Consequently, the firm has disaggregated and became a network. No firm is an island.

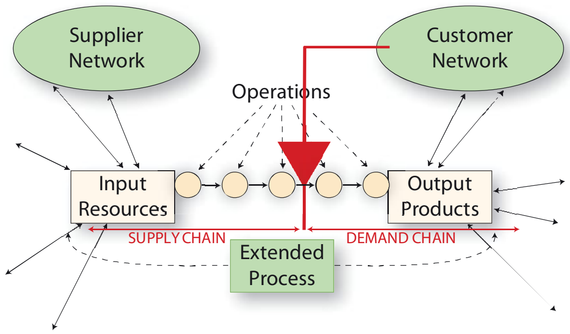

Figure 4. Extended process and Customer Intervention Point

5. Distributed process. This emerging stage represents the most radical business refocusing so far. Through the global sourcing, sections and components of the internal process are being outsourced to external providers and contractors in search of the highest added value contribution. Long-term alliances are formed and companies are transforming themselves into networks. Network cooperation is replacing corporate competition: 'coopetition' emerges. Globally distributed process ushers in new forms of organization, coordination and modular integration. This is graphically captured in Figure 5. / Figure 5).

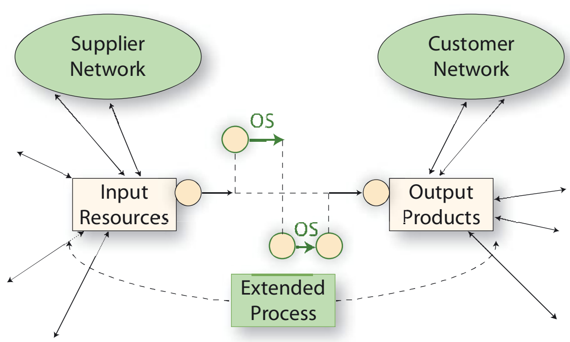

Figure 5. Distributed process and Outsourcing

Different parts of the extended process are geographically distributed and often spatially remote. In Figure 5, this distribution is represented by sections OS of the process which have been outsourced to higher added-value providers.

It is useful to note that the incessant and accelerating paradigm shifting is carried on mostly by the leading global players. The majority of companies (and educational and training institutions) could still be in the first, i.e. immediately post-war stage of the Final product focus; even the early process-orientation shift might have eluded them.

Although the Stage 5 (Figure 5) represents the most radical business refocusing emerging so far, one can already discern rapidly emerging kernels of the next stage (Figure 6). The evolutionary process, driven by relentless global search for maximum added value, is clearly accelerating. Management systems paradigm or business model, after a century of relative invariance, is becoming a new dynamic source of competitive advantage.

Radically distributed supply and demand chains of Stage 5 will clearly have to be coordinated and re-integrated on a global scale. Reintegration processes are proceeding under increasing environmental pressures. The search for added value, after exploring traditional global resources, is now turning towards reuse, recycling, recovery and remanufacturing as new sources of maximizing added value. Innovation in business models will become a norm.

So we observe the asset-recovery (Dell, IBM, Xerox) practices expanding quickly to a majority of products and services. New products are being designed for extended life spans and multiple profit cycles. Reverse logistics and reverse logistics management (RLM) are adding new loops to the traditionally unidirectional processes of supply chains. Concepts of easy disassembly, durability, reuse and recycling are built in into equipment design.

In Figure 6, the new loops are not just traditional information feedback loops, but real business processes of collection, disassembly, reprocessing and reassembly activities (operations). The conventional open-ended linear processes are being redesigned towards closure.

6. Recycled process. New loops of recycled products and materials, energy recovery and knowledge renewal are being created within global-sourcing (GS) networks. Product reuse/remanufacture relies on a high residual value which gives a good head start for added value maximization. The system becomes organizationally closed and potentially long-term sustainable or even trans-generations self-sustainable. The "openness" and customization of the product design, upgradeable products, flexible product platforms, mutability and waste-free strategies are being implemented. Of course, new employee skills and managerial knowledge, as well as essential mass customization mindset have to be produced, maintained and renewed. Eliminating non-value added resources and activities as well as integrating production system elements and work functions are also necessary.

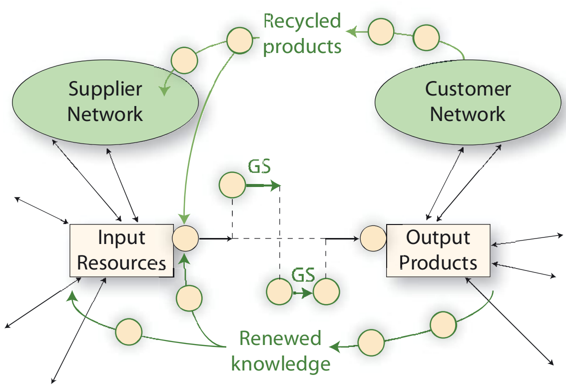

Figure 6. Recycled Process and Global Sourcing

7. Eco-technology

One of the newly emerging high technology is eco-technology: making ecology good business, not just bad politics.

The existing technology support net (TSN) is significantly appropriate for the old-fashioned burning of fossil fuels and use of non-renewable resources. The lack of a new TSN significantly hampers innovation and prevents introducing ecologically cleaner products, processes and business models. Only clear economic and business advantage shall usher in alternative technologies as high technologies. The accelerating competition for oil, taking its price well over $100/barrel plus increasing eco-taxation, is making alternative sources of energy more competitive. The search for corresponding technology and business innovations is on.

Ecology is good business! As soon as this becomes an accepted reality, the forces of capitalism and human greed will take over and clean up the environment much more effectively than any political "green" movements, consumption curtailing and redirection or cultural re-education. Capitalism brought about the energy crisis and environmental degradation, but only capitalism can replace the old TSN with a new one, and so bring forth the clean up of the environment with equal vigor, speed and ruthless perseverance. Once the new appropriate TSN is established and accepted habitually, then even a precipitous drop in oil prices would not bring the nonrenewable energy sources back in business.

The processes of recycling, resource recovery, material reduction, product reuse, remanufacture and systems redeployment lead to innovation and the reinstatement of the business life-cycle.

Old supply chains have become demand chains and now reverse value chains, demonstrating that value can be added in both directions: through the forward pass of production as well as through the backward pass of recovery and remanufacture. Both directions are value-adding processes, as in all of nature.

In the next "green section" we outline some typical and more promising examples of eco-technology. The automobile industry, being perhaps the largest eco-polluter and operating under the strongest lobby of global oil producing companies, provides also the strongest examples of emerging eco-business.

General Motors EV1. The electric vehicle EV1 evolved from the ZEV (Zero Emission Vehicle) mandate for California of the 1990s.

In late 2003, GM officially cancelled the EV1 program, despite the growing waiting lists, positive feedback from the users and accelerating movement towards ZEV laws. GM stated that it could not sell enough of the cars to make the EV1 profitable. All EV1 leases required return of the vehicle at lease end; the last private EV1 lease expired in August 2004. GM charged former lessees for excess wear and for scratches on the EV1s. All of the vehicles were scrapped and destroyed at the GM Desert Proving Grounds in Mesa, Arizona, much to the protest of their former users.

Yet, the EV1 was produced for the consumer market, and most lessees found driving an EV1 to be a favorable experience. On that basis, EV1 would qualify as the most successful electric car ever built. GM similarly disposed of 492 copies of its Chevrolet S10EV electric pickup truck. Such is the power of the TSN inertia and big oil lobby that even the most successful inventions cannot become innovations, even at the cost of the squandering potential technological advantage GM built through this program.

Among the ingenious inventions of the EV1 (aluminum frame, dent-resistant panels, anti-lock brakes, traction control, heat pump, keyless ignition, one-way thermal glass, regenerative braking, magnesium alloy wheels, self-sealing tires, etc.) was the Ovonic nickel-metal hydride battery. The EV1 got 75 to 150 miles per charge, recharging took as much as eight hours for a full charge (80% charge in two to three hours). A modified EV1 prototype set a land speed record for production electric vehicles of 183 mph in 1994. With the help of a continuously variable transmission, the car accelerated 0 to 60 mph in 11 seconds. The maximum range was 350 to 400 miles, and fuel economy was 60 mpg (in gasoline equivalent). Many EV1 lessees offered to purchase their vehicles from GM at lease-end for the residual price. For instance, US$1.9 million was offered for the remaining 78 cars in a Burbank storage lot. GM did not entertain any of such offers. Nearly all of the EV1s being decommissioned by GM were crushed and recycled as scrap metal. The Smithsonian Institution announced that its EV1 display was being permanently removed and the EV1 car put into storage.

GM purchased the battery patents from the inventor, Stan Ovshinsky in 1994, forming „GM Ovonics" under the guise of going into production with the EV1. GM's true intention became apparent when in October 2000 they sold their control of the EV1 batteries to Texaco. Less than a week later, Chevron purchased Texaco in a $100 billion merger. All these patents are now in the corporate safes of Chevron and no such NiMH batteries are available for EVs. The cycle has been closed, a new technology affectively thwarted.

An EV1 is still on display at The Henry Ford Museum in Dearborn, Michigan, and one more in the Petersen Automotive Museum.

Tesla Roadster. Because of the EV1 fiasco, the Tesla Roadster (TR) is now one of the world's first high-performance electric cars. Compared to traditional internal combustion engines, the TR does not need hundreds of moving parts to create friction and heat. It is powered by just four main systems: Energy Storage System (ESS), Power Electronics Module (PEM), electric motor and sequential manual transmission. Like the Japanese Eliica, the TR uses rechargeable lithium-ion batteries, and one can install a recharging station in a garage. This 220-volt, 70-amp outlet allows for a full recharge in 3.5 hours from a completely dead battery. There is also a mobile kit that allows recharging at any electrical outlet.

The heart of the Tesla Roadster is its electric induction motor, which weighs just 70 pounds. The Roadster can reach 60 mph in about four seconds and its top speed is somewhere around 130 mph. There is no need for a complicated transmission, so the Roadster has just three gears -- two forward gears and one reverse gear. Shifting is manual, but there's no clutch. The Roadster's estimated range is 250 miles on a single charge, at least 100 miles more than General Motors' EV1.

Produced by the Tesla company of California (with no connection to the traditional American auto industry), its founder Martin Eberhard had no experience in the auto industry when he decided to create the world's first high-performance electric car. Frustrated by the mainstream auto industry's inability to create an effective electric car, he decided to create one himself. Eberhard took advantage of outsourcing, which made the various elements easy to acquire. The new company derived their design from the Elise, of England-based Lotus.

Tesla plans a 2008 release of a four-door electric sedan (codenamed White Star). The first 100 limited edition „Signature Series" Roadsters sold out, and the next run of 100 is ready for pre-orders. An electric car has zero emissions and does not add to pollution. The Roadster already offers double the efficiency of popular hybrid cars, while generating one-third of the carbon dioxide. It could go 150 miles for the price of one gallon of gas. Driving an electric car costs a fraction of what it costs to drive a gas-powered car. But the energy to power an electric car still comes from the existing electrical grid. The solution is the car that generates its own electricity, like Eliica.

Eliica. The name stands for Electric lithium-ion car, developed by 40 students of professor Shimizu at the Keio University in Japan. The KAZ Eliica is an eight-wheeled, electric-powered limousine with impressive performance credentials. It evolved from Keio's KAZ Electric Car (the Keio Advanced Zero-Emission).

The design team's goal was to beat the top speed of the Bugatti Veyron and build a limited production run spanning around 200 units, allowing it to hold the record as the world's fastest production vehicle. The Eliica outclasses the speed and acceleration of many current super cars.

The key feature is the old Porsche's idea of using each wheel as an independent electric motor, spelling the end of the classical central engine. Eight in-wheel electric motors and a bank of lithium-ion batteries power the Eliica. It runs faster than any other concept in its class and reaches top speeds of an unbelievable 240 mph. It boasts a 0 to 60 mph acceleration of only 4.1 seconds, faster than numerous engine-powered vehicles of its size. There is also a popular model which limits driving speed at 115 mph but allows a range of 200 miles before recharging.

Electric cars preceded the internal combustion engine and dominated the market for many decades. But because the gasoline-powered car was cheaper and evolved its own TSN faster, electric cars faded away. There were no pollution and emission concerns at the time. Porsche's zero-emission design of a distributed engine (electric motors in the wheels) was inappropriate for the dominant TSN of gas, oil and coal. Now electric cars are making a comeback and represent the future of the automobile industry. They are clean, convenient and cheap; they are a good business, not just political statements about "saving the world," even though the world would clearly be safer if every region produced its own energy in a sustainable, environmentally-sound manner.

Electric vehicles are user-friendly. They never need an oil change or new spark plugs. They use a regenerative braking system, so brake pads and rotors last several times longer than those in a gas-powered car. The simplified drive train not only makes EVs more reliable, it also results in much lower maintenance costs. Companies such as A123 and Altairnano are currently developing lithium-based batteries with dramatically longer lifespans than those of current Li-Ion batteries.

The costs can go down to a retail price equivalent of $10,000 per drive train if a company could manufacture between 50,000 and 100,000 units per year. Costs would fall much further with the increasing volume. There is also the Chevrolet Volt, planned for release in 2010, which will have a total range of 390 miles per charge. But electricity is not the only alternative energy source: there is also CAT (Compressed Air Technology)

MDI Air Car. Air cars are powered by central engines, but use compressed air instead of pressurized combustion gases. The air storage tank is made of carbon-fiber of low weight and high strength. Instead of mixing fuel with air and burning it to drive pistons with hot expanding gases, air cars use the expansion of compressed air to drive their pistons. They would of course also benefit from the distributed engine concept, powering the wheels directly.

CAT cars have designed safety features to avoid hydrogen's propensity to damage and danger involved in high-impact crashes. Air is obviously absolutely clean and non-flammable. They in fact release air cleaner than they receive, because of air filtering. There are currently models designed by Mitsubishi, MDI, Tata Motors and ZAP. Unlike electric or hydrogen powered vehicles, MDI vehicles are not expensive and do not have a limited driving range. MDI cars are affordable and have a performance rate that stands up to current standards.

As soon as gas-powered engines are heavily penalized or prohibited in cities, like in the city center in London, MDI's CAT models Onecats, Minicats and Citycats will become the sought after vehicles. The first air cars should become available in summer 2008: Onecat at 3,500€ and 5,300€, Minicat at 6,860€ and Citycat at 9,460€.

Especially in rapidly developing countries like China and India, the need for a cheap, zero-emission, effective vehicle has become a geopolitical strategic issue. That is why Indian Tata Motors and French MDI Group have formed a cooperative alliance in 2007.

Genepax Water Car. Another electric-powered car that runs solely on water was unveiled by Genepax in Osaka in June 2008. One liter of any kind of water - rain, river or sea - gets the engine going for about one hour at a speed of 80 km/hr. this one does not require to build up a new support infrastructure for recharging batteries, as is the case for most electric cars. Once the water is poured into the tank at the back of the car, a generator breaks it down and uses it to create electricity. Japanese company, Genepax has claimed that it has created a new eco-friendly car that can run on nothing but water. The proprietary unit, a membrane electrode assembly (MEA), breaks water into hydrogen and oxygen using a chemical reaction, which provides energy for a hydrogen fuel cell to run the car.

A 300W system is mounted in the luggage room of a compact electric vehicle „Reva" manufactured by Takeoka Mini Car Products. Genepax is planning to produce 1kw-class generation systems for use in electric vehicles and for residential applications. While the current production cost is about $18,522, it is estimated to be reduced to $5000 and lower as soon as the company succeeds in mass production.

Figure 7. Genepax Water Energy System (WES) Electric

Tata Pace Car. Tata Motors is India's largest automobile company, with revenues of US$ 5.5 billion in 2005-06. Progressive car companies are coming up with new ways to develop and build automobiles worldwide. In 2008, Tata Motors is scheduled to introduce its long-awaited People's Car („one-lakh car"), with a sticker price of about $2,500. India's emphasis is on small, low-cost cars — but with four doors and room for the extended family.

Maruti's factory in Gurgaon, south of New Delhi, has created a self-sufficient, streamlined island: 4,700 Maruti employees work inside together with as many employees of suppliers, whose warehouses and production plants ring Maruti's main factories. This is co-location (supplier integration) at its best. The site generates its own electricity and recycles its own water. Inside the main factory are all the materials the company needs for two hours of production at the current rate of one car built every 21 seconds.

Maruti, majority owned by Suzuki, has plans to increase its already highly automated process, with the goal of cutting its production time in half and trimming costs. Already, giant swiveling robots do much of the welding. Manpower is employed mostly to check for errors. Nothing like that can be seen in Detroit. This is India at its best.

Chrysler's CCV (Composite Concept Vehicle), explicitly designed in the 1990s for developing nations like China and India, went the way of GM's EV1: Chrysler's 1998 takeover by Daimler-Benz effectively killed the project. The strategic blunders of the US auto manufacturers appear to be boundless.

Maruti's factory's self-sufficiency and closed production cycle represents a new business model for making environment friendly cars in an environment friendly way. Here, the Japanese lead the way.

Subaru's Zero-Waste. The Subaru factory in Lafayette, Indiana, recycles all its waste. A single American household generates more trash than the manufacturing processes at the Subaru factory. It is the first auto assembly plant in North America to become completely waste-free. In 2004, 100 percent of the waste steel, plastic and other materials coming out of the plant were reused or recycled. What can't be reused -- about 3 percent of the plant's trash -- is shipped off to Indianapolis and incinerated to generate electricity. No landfills is the goal.

Subaru represents a trend in new business model innovation: In 2001, HP managed to keep just over three-quarters of its trash out of landfills around the world. Now that figure is 84 percent. Xerox is reusing or recycling 90 percent of its waste. Three of Toyota's manufacturing plants in the United States have reached the 95 percent level, as has Fetzer Vineyards, one of the country's largest winemakers. Ecology is good business! Anything that is waste is also inefficiency in the process, and any inefficiency is lost dollars.

Subaru has made reducing waste a part of its plant managers' performance evaluations. They develop projects to improve recycling and reduce the amount of waste. The best way to cut waste is not to produce it in the first place. The biggest win is not recycling, but reengineering material out of the product and process so that there are no landfill needs.

Ricoh's Zero Waste. Ricoh Electronics received in 2004 the State of California's top waste reduction environmental award for outstanding achievement in on-site recycling, materials reuse and waste prevention. Zero waste is a way of life at Ricoh Electronics. This global firm defines leadership and excellence in every aspect of its business and has achieved an exceptional level of waste reduction in its daily operations. They diverted over 3,622 tons of waste through the recycling efforts of each employee. The company also saved more than $2.5 million as a result of its employee-driven Environmental Sustainability Improvement Activities.

At Ricoh, every employee is a process owner. Employees are encouraged to improve their work processes to reduce paper and water use, as well as to conserve electricity and reduce other types of waste. The business incorporates environmental issues into its mission and daily operations as part of a commitment to its remarkably successful "Zero Waste to Landfill" system.

Zero Waste represents a new business model that profoundly changes corporate approaches to resources and production. It is not just about recycling and diversion from landfills, but it also restructures production and distribution systems to prevent waste from being manufactured in the first place. Whatever materials are still required in these redesigned, resource-efficient systems are being recycled right back into production. Zero Waste models are based on several basic principles:

- Preventing rather than managing waste.
- Discarded resources turned into jobs instead of trash.
- Self-sustainable economy provides for a comfortable regional society without penalizing future generations.
- Natural systems are emulated where everything that wears out or dies becomes food or shelter for something else, forming the biocycle of business.

8. Conclusion

The closed-loop management system (Fig. 6) represents a qualitative change in the support net for requisite closed-loop, closed-system technologies. Technology support network (TNS) is the primary criterion for technology innovation. Without matching the support network, any new technology has very little chance of succeeding. Modern innovation process has to pay more attention to matching (technology) or qualitatively changing (high technology) the requisite support net. The support net itself has to be designed in a most flexible, mobile, minimal and customer-controlled fashion. The continued efforts of support net "stakeholders" to maximize their revenue streams through its technical, economic, social and political fixation are the main cause of only perfunctory hardware innovations and the lack of true paradigmatic progress in many areas of support net dependent technologies. Support-net oriented research, design and implementation of high-technology innovations is increasingly required and mandated by global competition.

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