Chapter 2

SERVICES INNOVATION: DECISION ATTRIBUTES, INNOVATION ENABLERS, AND INNOVATION DRIVERS

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Abstract: Innovation in the services area – especially in the electronic services (e-services) domain – can be characterized by six decision-oriented attributes: decision-driven, information-based, real-time, continuously-adaptive, customer-centric and computationally-intensive. These attributes constitute the decision informatics paradigm. In turn, decision informatics is supported by information and decision technologies and based on the disciplines of data fusion/analysis, decision modeling and systems engineering. Out of the nine major innovation enablers in the services area (i.e., decision informatics, software algorithms, automation, telecommunication, collaboration, standardization, customization, organization, and globalization), decision informatics is shown to be a necessary enabler. Furthermore, four innovation drivers (i.e., collaboration, customization, integration and adaptation) are identified; all four are directed at empowering the individual – that is, at recognizing that the individual can, respectively, contribute in a collaborative situation, receive customized or personalized attention, access an integrated system or process, and obtain adaptive real-time or just-in-time input. In addition to expanding on current innovations in services and experiences, white spaces are identified for possible future innovations; they include those that can mitigate the unforeseen consequences or abuses of earlier innovations, safeguard our rights to privacy, protect us from the always-on, interconnected world, provide us with an authoritative search engine, and generate a GDP metric that can adequately measure the growing knowledge economy, one driven by intangible ideas and services innovation.

Key words: Services; innovation; decision informatics; software algorithms; automation; globalization; collaboration; customization; integration; adaptation; standardization; telecommunication; organization.

1. INTRODUCTION

Sometimes invention or discovery is mistaken for innovation. Robert Metcalfe, the inventor of the Ethernet protocol and the founder of 3Com, observes that "invention is a flower, innovation is a weed; that is, an original idea can be brilliant, profound and compelling – but what ultimately gives it power and influence is that it spreads [like a weed]". Thus, while inventions are to be celebrated, businesses must rely on innovations to survive and grow; in this regard, successful innovations are those that spread in terms of reach, impact, and/or commercial success. Although ingenuity, talent, analytical skills, focus, and perseverance are required to achieve either, an innovation does not necessarily depend on an invention (e.g., witness the thousands of commercial successes that are not based on any invention); likewise, an invention does not necessarily result in an innovation (e.g., witness the thousands of patents that have never been commercialized).

Automation underpins most of the innovations in the past century. In the first two-thirds of the 20th Century, electrification was the engine of automation, while in the latter third it has been the computer chip which – together with electrification and digitization – has made automation a flexible and intelligent mechanism. Indeed, as listed in Table 2-1, electrification is first among the top 20 achievements in the 20th Century, as compiled by the National Academy of Engineering (NAE) [2000]; it can be credited with spawning most, if not all, of the remaining 19 achievements, including the Internet and the continuous upgrading of the automobile, the airplane, the telephone, etc.

Table 2-1. Technological Innovations

• **National Academy of Engineering's Top 20 Engineering Achievements in the 20th Century:**	
1. Electrification	11. Highways
2. Automobile	12. Spacecraft
3. Airplane	13. Internet
4. Water Supply and Distribution	14. Imaging
5. Electronics	15. Household Appliances
6. Radio and Television	16. Health Technologies
7. Agricultural Mechanization	17. Petroleum and Petrochemical Technologies
8. Computers	18. Laser and Fiber Optics
9. Telephone	19. Nuclear Technologies
10. Air Conditioning and Refrigeration	20. High-Performance Materials
• **Possible Additional Achievements in the Early 21st Century:**	
21. Information Technology	
22. Nanotechnology (Nanomaterials, Nanotubes, Nanoelectronics)	
23. "Technobiology" (New Drugs, DNA Chips, Bionic Parts)	

Source: *National Academy of Engineering*, 2000

While Table 2-1 lists NAE's top 20 for the last century, we have also added three possible additional achievements for the early 21st Century: information technology, nanotechnology, and, what we define as, "technobiology." (Technobiology emphasizes the contribution of engineering or technology to biological issues, including the development of new drugs, DNA chips, and bionic parts; in contrast, biotechnology emphasizes the contribution of biology to technological issues, including the development of molecular computers, cognitive ergonomics, and neural networks.)

Returning to information technology, it should be noted that its key underpinning – the computer chip – has only been in existence for five decades; the first commercially available computer – the Universal Automatic Computer or Univac I – was built in 1951. Nevertheless, computers have already evolved through several generations. As indicated in Table 2-2, Intel's first chip – the 4004, introduced in 1971 – had only 2200 transistors per chip; today, there are several hundred million transistors per chip. Indeed, Gordon Moore [1965], co-founder – with Robert Noyce – of Intel, conjectured that the number of transistors per square inch of an integrated circuit would double every year, as it had up to 1965. In subsequent years, however, the pace has slowed down, with the data density doubling approximately every 18 months; this is now the current definition of Moore's Law, with which Moore himself has concurred.

Table 2-2. Computer Chip: The New Engine of Automation

Year	Intel Chip	Transistors Per Chip	Milestone
1971	4004	0.002M	Transformational beginning.
1972	8008	0.003M	--
1974	8080	0.005M	Inside first personal computer (Altair 8800).
1978	8086	0.029M	--
1982	286	0.120M	--
1985	386	0.275M	--
1989	486DX	1.180M	Introduction of a math coprocessor.
1993	Pentium	3.1M	Powers 85% of world's desktops.
1997	Pentium II	7.5M	--
1999	Pentium III	24.0M	--
2000	Pentium 4	42.0M	Powers portable computers and mobile devices.
2001	Ithanium	25.0M	--
2003	Ithanium 2	220.0M	--

Source: *Intel Corporation*, 2004

Today, the G5 processor chip – jointly developed by IBM and Apple – is based on a 64-bit architecture and possesses a speed of one gigahertz. Additionally, Advanced Micro Devices Inc. is producing multicore chips that may well become the industry standard. Most experts expect Moore's Law for smaller, better, faster and cheaper chips to hold for at least another two decades, although flexible plastics may well replace silicon as the material of choice for computer chips. In fact, a plastic screen was recently used on a digital camera from Kodak, which in 1979 discovered the first organic light-emitting diodes (OLEDs). In contrast to the liquid crystal displays (LCDs) in cell phones and computers, OLEDs do not break when dropped, save energy (since they generate their own light), and possess more vibrant colors.

An essential and complementary technology to the computer chip is, of course, software. Software contains the programs, routines, and procedures that control the functioning of the hardware (i.e., computer chips) and direct their operation. The two major categories of software are "system software" and "application software." System or platform software includes the basic input-output system (often described as firmware rather than software), the device drivers, an operating system, a database management system, and typically a graphical user interface which, altogether, allow a user to interact with the computer and its associated equipment or peripherals. Application software is any program that processes data for the user (e.g., inventory, payroll, spreadsheet, word processor, etc.); it is usually independent from the operating system, even though it is often tailored for a specific platform. An algorithm is a special application software; it refers to a set of ordered steps for solving a complex problem, such as a mathematical formula. As a consequence, software algorithms provide the means for automating innovations in modern, electronic-based goods and services (including experiences). Automating a services process, for example, through a carefully developed algorithm is, of course, a crucial step in enhancing productivity. Otherwise, extensive manpower is required to manually co-produce the services, a situation which would contribute to "Baumol's Disease". Baumol et al. [1989] recognized the connection between slow productivity growth and rising costs in certain stagnant industries within the services sector. Although automation has certainly improved productivity and decreased costs in some services (e.g., telecommunications, Internet commerce, etc.), it has not yet had a similar impact on other labor-intensive services (e.g., health care, education, etc.). In regard to software development itself, there is unfortunately no comparable Moore's Law in effect; however, standardization and supporting tools have improved software productivity.

Another critical underpinning of information technology is telecommunication. Although computers (i.e., mainframes) tended to centralize data and – data-based – decision making in the 1960s and 1970s, the advent of computer networks, together with personal computers (PCs), have been a decentralizing (i.e., less hierarchical) force. The most important and indispensable network is, of course, the Internet; it is becoming a platform for commerce (i.e., Web 2.0), whereby trillions of computers and sensors will be interconnected and will, in essence, diminish distance as an impediment for collaboration and commerce [Cairncross, 1997]. Companies like Wikipedia, Flickr and MySpace are leading the way to making Web 2.0 style of interconnection and collaboration a reality. Furthermore, new wireless telecommunication advances will soon make mobile devices a multi-purpose services instrument, with more memory and better screens and where traditional voice and data (i.e., Internet and email) services will converge with digital music, video clips, video conferencing, satellite radio, location tracking, traffic reporting, and other personal needs (e.g., credit checks, online education, etc.). All of these technological innovations – which are based on real-time computing – have ushered in a range of real-time or on-demand enterprises, which claim that critical business information is always up-to-date and available and that decisions can be promptly made; that is, the detection of an event, the reporting of that event, and the response decision can all occur within a very short time frame or near real-time. Clearly, as examples, the slow and inadequate responses to recent urban disruptions (e.g., 2001 9/11 tragedy, 2002 SARS – Severe Acute Respiratory Syndrome – epidemic, 2004 South Asia Tsunami, and 2005 Hurricane Katrina) demonstrate that although real-time actions are desirable, they are not a pervasive reality. On the other hand, Amazon does employ real-time information technology and automated decision making to suggest alternative reading material for its customers. Thus, real-time decision making is not only about real-time computing but also about developing the tools or algorithms to support real-time actions and activities.

Interestingly, economists claim that because of the astounding growth in information technology, the U. S. and other developed countries are now a part of the global “knowledge economy”. Although information technology has transformed large-scale information systems from being the "glue" that holds the various units of an organization together to being the strategic asset that provides the organization with its competitive advantage, we are far from being in a knowledge economy. In a continuum of data, information, and knowledge, we are, at best, at the beginning of a data rich, information poor (DRIP) conundrum. The fact remains that data – both quantitative and qualitative – need to be effectively and efficiently fused and analyzed in order to yield appropriate information for intelligent decision making in regard to the design, production and delivery of goods and services. Today, retailers complain, "We are awash in data but starved for information." Thus, in order to overcome the somewhat embarrassing DRIP problem that Tien [1986] forewarned, it is critical to develop more sophisticated data fusers and data analyzers – as a part of what Tien [2003] calls "decision informatics" – that could yield the information or knowledge required for making smart choices [Hammond et al., 1999] or for developing new, and possibly disruptive, innovations. Indeed, we augur in Section 3 that decision informatics should be considered to be a critical enabler of services innovation.

In sum, although information technology facilitates robust and timely decision making; a necessary condition is one based on decision informatics or real-time, information-based decision making. Clearly, information, telecommunication, software and real-time decision making technologies, together, provide for a supportive environment within which innovations in goods and services can continue to flourish. This has been strikingly demonstrated by Wal-Mart with its point-of-sale information system, which is at the heart of its services value chain; the system has had a significant impact on the company's productivity gains, cost controls, services quality, and ultimately growth.

In the remainder of this paper, innovation enablers, services sector and decision informatics are, respectively, discussed in Sections 2, 3 and 4; they provide the framework for identifying past and future services innovation in Section 5. Some concluding remarks are made in Section 6.

2. INNOVATION ENABLERS

Given the importance of innovation to the economies of the world, it is not surprising that it is a topic of intense interest in both the popular and academic presses. Moreover, governments are also getting involved in helping their enterprises succeed in developing high-value innovation in services [OECD, 2005; NMIT, 2006]. For example, in response to the recommendations made by the Council on Competitiveness, the U. S. Congress [2005] is considering a National Innovation Act. This legislation focuses on three primary areas of importance to maintaining and improving U. S. innovation in the 21st Century: a) research investment, b) increasing science and technology talent, and c) developing an innovation infrastructure. The legislation also establishes a President's Council on Innovation, with responsibility for developing a comprehensive agenda that can promote innovation in the public and private sectors. In consultation with the Office of Management and Budget, the Council is to identify and employ metrics to assess the impact of existing and proposed laws that affect U. S. innovation. In addition, the Council is to coordinate and assess the performance of various Federal innovation programs, and an annual assessment report is to be submitted to the President and to the Congress.

Innovation requires changes or recombination of processes, products and businesses, including people, technologies, systems, attitudes, values, cultures and organizational structures. For each of the past two years, *BusinessWeek* and The Boston Consulting Group have surveyed about 1,000 senior managers from around the globe to ascertain the 25 most innovative companies. Table 2-3 summarizes the two annual surveys; it is seen that 20 of the top 25 companies in 2006 undertook product innovations, 14 undertook business model innovations, and 13 undertook process innovations. It is also seen that these 25 innovative companies had an average annualized 1995-2005 stock return of 14.3 percent, suggesting that innovation does pay off, at least in comparison with the Standard and Poor's 1200 Global Index, which had an 11.1 percent annualized stock return over the same decade. In examining the 25 companies' primary focus of innovation, it can be determined, to the best of our judgment, that 16 of them (i.e., 64%) are focused on services innovation and 9 (i.e., 36%) on goods innovation. This observation is consistent with Berg and Einspruch's [2006] findings. Of course, some innovations can be considered to impact both goods and services; thus, for example, we classify Apple's iPod and iTunes as primarily a services innovation, inasmuch as these goods have served to promulgate a major new service – indeed, a new experience.

In trying to identify innovation enablers, it should be noted that the enablers may differ between those for goods and those for services, and may further differ over time. For example, in the latter part of the 20th Century, innovation was about technology and control of quality and cost for goods; in the beginning of this 21st Century, the focus is on rewiring the processes, products and business models in order to achieve efficiency and growth in the services sector, especially since goods have become more and more commoditized. Our focus is, of course on those enablers that can enhance services innovation. In general, there are at least nine major innovation enablers in the services area: 1) decision informatics, 2) software algorithms, 3) automation, 4) telecommunication, 5) collaboration, 6) standardization, 7) customization, 8) organization, and 9) globalization. The first four have been addressed in Section 1, although decision informatics is further discussed in Section 4. The remainder of this section considers the remaining five enablers: collaboration, standardization, customization, organization, and globalization.

Table 2-3. Most Innovative Companies in 2006

Survey Rank		Company	Innovation Areas			Annualized 1995-2005 Stock Return	Innovation Focus Goods (G), Services (S)
2006	2005		Process	Product	Business		
1	1	Apple		✔	✔	24%	S: iPod, iTunes, Experience
2	8	Google		✔	✔	--	S: Search Ad Clicks, Mash-Ups
3	2	3M		✔		11.2%	G: Post-It Pictures, Research
4	14	Toyota	✔	✔		11.8%	G: Manufacturing, Value Chain
5	3	Microsoft		✔	✔	18.5%	S: Integration, Live
6	3	General Electric	✔	✔		13.4%	S: Imagination, Courage
7	9	Procter & Gamble	✔	✔	✔	12.6%	G: Intra-Collaboration
8	9	Nokia	✔	✔	✔	34.6%	S: Emerging Markets
9	19	Starbucks		✔	✔	27.6%	S: Media Bars, Experience
10	7	IBM	✔	✔	✔	14.4%	S: Open Invention Network
11	11	Virgin Group			✔	Private	S: Lifestyle
12	12	Samsung	✔	✔		22.7%	G: Speedy Product Cycles
13	5	Sony		✔		5.1%	G: High-Definition
14	6	Dell	✔		✔	39.4%	S: Supply Chain, Sales Channels
15	18	IDEO	✔	✔		Private	S: Palm V, Leap Chair
16	20	BMW	✔	✔		14.2%	G: Competitive Designs
17	16	Intel		✔	✔	13.8%	G: New Products
18	15	eBay			✔	--	S: Online Market, Fixed-Price

19	--	IKEA	✔	✔	✔	Private	G: Affordable Designs
20	13	Wal-Mart	✔			16.2%	S: Supply Chain
21	16	Amazon	✔	✔		--	S: Web Services
22	--	Target		✔	✔	25.2%	S: Discount Marketing
23	23	Honda		✔		12.9%	G: Engineering, Beyond Auto
24	--	Research In Motion		✔		--	S: Black Berry, Wireless Email
25	21	Southwest Airlines	✔		✔	13.9%	S: Operations, Low-Cost
Overall						14.3%	G: 9 (36%); S: 16 (64%)
Standard and Poor's 1200 Global Index						11.1%	

Source: *BusinessWeek*, April 24, 2006

Collaboration – especially inter-company collaboration – is perhaps the most surprising enabler. After all, patents were established to protect intellectual property, long enough for the inventors to recoup a good return on their creative investment. However, since services are, by necessity, co-created or co-produced, collaboration is essential. Indeed, von Hippel [2005] found that 40 percent of a company's customers modify its products in some way so as to better suit their needs. Moreover, as noted by Palmisano [2004], the innovation challenges are too complex; they require collaboration across disciplines, specialties, organizations and cultures. Additionally, the easy access to information through search engines (e.g., Google, AOL, Yahoo, Microsoft Network, etc.), the proliferation of collaborative software (e.g., Microsoft Office Live Meeting, MySpace), and the open source software movement (e.g., Linux, Open Invention Network) have all combined to facilitate collaboration. (In 2005, IBM gave – royalty free – 500 software patents to the Open Invention Network.) Chesbrough [2003] lauds IBM's open innovation outlook (especially as compared with Xerox PARC's closed approach); Govindarajan and Trimble [2005] recommend that past assumptions, mindsets, and biases must be forgotten (especially in regard to collaboration); and Sanford and Taylor [2005] further underscore this point by suggesting that companies must "let go to grow".

The National Science Foundation [2006] recently initiated the Partnerships for Innovation program that seeks to bring together researchers from academe, the private sector, and government for the purpose of exploring new innovation partnerships. Amazon has taken a giant step in collaboration; through the Amazon Web Services effort, it has, in essence, given its software (including personalization functions) and a good portion of its actual sales to thousands of software developers, who are finding – for a fee – innovative ways of connecting Web surfers to Amazon merchandise. Obviously, companies are collaborating not because they wish to give away their business, but because they wish to grow the business. On the other hand, a large number of individuals are collaborating – for free – to enhance an open source software (e.g., Apache), to network, including meeting new friends, sharing photos, or emailing internally (e.g., MySpace), to play a global game with guilds and imaginary gold (e.g., World of Warcraft), or even to live in a virtual world with individualized avatars and Linden dollars (e.g., Second Life), all to satisfy their creative, if not altruistic, and competitive needs. There is much to learn about collaboration, organization, and other real-time business applications from the always-on virtual world. In fact, the real-world is using Second Life type of environments to introduce and test new ads, to train new hires, and to design and market new products. Of course, the two worlds are becoming more intertwined when virtual land development companies act in a very realistic manner and when 300 Linden dollars can be exchanged for one U. S. dollar.

A critical by-product of collaboration is standardization. Standards establish clear boundaries of function and operation, eliminate data interface problems, define interchangeable components and platforms, and assure a high level of performance. Even with standards, there can be misunderstandings. A case in point is the difference between two wireless technologies: Wi-Fi (IEEE 802.11 standard) and WiMax (IEEE 802.16 standard). Wi-Fi is designed to be used indoors at close range, to connect a group of computers in an office or home to each other and to the Internet; on the other hand, WiMax allows devices atop buildings and towers to feed Internet service to appropriately equipped computers at broadband speeds and up to 50 kilometers away. In time, a high-end mobile device could have both capabilities, so that one can seamlessly move from a Starbucks Wi-Fi hotspot to an automobile with a WiMax capability. New wireless standards will have to be established as more sophisticated wireless technologies are introduced, including smart antennas (which, instead of sending a weak omni-directional signal, can adaptively focus its signal for maximum distance), mesh networks (which employ the ongoing connections among users as a part of its own adhoc network), and agile radios (which can communicate among a number of frequency bands, depending on which parts of the spectrum are free). Another area of standardization is at the interfaces of these technologies. For example, when cellular networks and Wi-Fi become seamless, cell phones will become an omnipresent device, capable of functioning in open space where cellular networks abound and within buildings where Wi-Fi dominates.

A cornerstone of standardization has been the ubiquitous bar code – called the Universal Product Code (UPC) – that has been uniquely associated with almost every good or service. The UPC is making way for the Electronic Product Code (EPC) which is stored in a radio frequency identification (RFID) tag or computer chip with a transmitter. The tags are being placed on pallets or individual items passing through the supply chain. When activated by a reader, the tags can send or receive information. Wal-Mart and the U. S. Department of Defense are beginning to mandate the use of RFID in the supply chain. The real question is how companies can go beyond compliance and derive real value from RFID. Suppliers implementing RFID face two sets of considerations: "before the beep" and "after the beep", where the "beep" refers to the point at which an RFID tag is read by a reader. Before the beep includes technical considerations to ensure that tags are properly encoded, affixed to pallets or cartoons, and positioned so that readers can obtain and interpret the data, while knowledge gleaned after the beep includes issues related to data management and abstracted information that could appropriately support or inform critical decision making. Early indications suggest that RFID can result in labor savings (as readers can replace employees by obtaining data from tags within 30 feet), revenue enhancement (as better inventory management can reduce inventory shrinkage), and more informed choices (as, for example, the elimination of unnecessary handling by automatically forwarding a product to the customer without having to go through a warehousing phase). Another benefit of employing RFID is speed; thus, whereas conveyor belts in a typical distribution center operate at about 20 to 30 feet per minute, the Wal-Mart mandate of 600 feet per minute is well within RFID's capabilities. Additionally, RFID can help suppliers take full responsibility for ensuring that the retailer's inventory is replenished on an as-needed basis, thereby eliminating lost sales due to out-of-stock merchandise. In essence, RFID serves to make the supply chains more visible in real-time, and as the price of tags decreases, RFID will become ever more popular and critical to the efficient functioning of any supply chain, including the distribution and shipping of goods.

In actuality, an RFID tag is just a digital sensor. Like all (including environmental and biological) sensors, standardization – which, in the RFID case, is the EPC – is required in order to understand the sensor's output. Depending on the type of sensor, other standards or protocols are required. As another example, IEEE 1451.4 is being promulgated to calibrate the output of analog sensors (e.g., temperature gauge) to digital signals.

Additionally, as with collaboration, standardization (based usually on best practices) allows a business to grow by reassembling itself – with interchangeable blocks of technologies, processes, expertise, assets, capital and information – as the customers or circumstances require. Paradoxically, although standardization facilitates and enables innovation in both goods and services, it also facilitates and enables commoditization (where fierce competition and price erosion are the norm). Thus, the cycle of life in innovation includes innovation, best practices, standardization, commoditization, and (new) innovation.

Another critical by-product of collaboration is customization. Tien et al. [2004] have identified several levels of customization. Partial customization occurs in an assemble-to-order environment; that is, upon the arrival of a customer order, the stocked components are assembled into a finished product. As examples, in addition to computer assemblers like Dell and Gateway, Nike offers a program called NikeiD that allows customers to choose the color, material, cushioning, and other attributes of their athletic shoe order, and Procter & Gamble allows women to create and order custom personal-care products such as cosmetics, fragrances, and shampoos. Another form of partial customization occurs when the customer market is partitioned into an appropriate number of segments, each with similar needs. For example, Amazon targets their marketing of a new book to an entire market segment if several members of the segment act to acquire the book, although its approach is neither massive nor timely at this time. Mass customization occurs when the customer market is partitioned into a very large number of segments, with each segment being a single individual. Customization of clothing, car seats, and other body-fitted products is being advanced through laser-based, 3-D body scanners that not only capture a "point cloud" of the targeted body surface (e.g., some 150,000 points are required to create a digital skin of the entire body) but also the software algorithms that integrate the points and extract the needed size measurements. For example, European shoe makers recently initiated a project called EUROShoE (*www.euro-shoe.net*), in which an individual's feet are laser scanned and the data are forwarded to a CAD/CAM computer that controls the manufacturing process. Likewise, electronics giant Toshiba wants to give Web surfers and walk-in customers new tools to view digital versions of themselves trying on clothes, accessories and make-up. Real-time mass customization occurs when the needs of an individualized customer market are met on a real-time basis (e.g., a tailor who laser scans an individual's upper torso and then delivers a uniquely fitted jacket within a reasonable period, while the individual is waiting). Tien et al. [2004] also suggest that goods and services will become indistinguishable when real-time mass customization becomes a reality.

The people, technologies, systems, attitudes, values, cultures and structures of an organization must likewise be flexibly aligned in order to facilitate and enable innovation, especially collaborative or open innovation. The CIO (Chief Information Officer) of yesteryear remains the CIO of today, except for the fact that the "I" now stands for Innovation and typically includes authority over the research and development activities of the organization. In fact, many research and development groups (e.g., Lucent's Bell Labs, Xerox's Palo Alto Research Center, IBM's T. J. Watson Research Center, and GE's Global Research) are being both redirected to focus on innovation and partitioned, with new locations in Europe, India, and China. Moreover, the qualifications for the new CIO position require not only an idea person but, more importantly, a persuasive individual who can adroitly navigate new, high-risk products and processes through the organization. Similar to the promulgation of total quality management in the 1990s, the Chief Executive Officer (CEO) is also getting personally behind the innovation initiative. Clearly, there is an organizational sea change occurring, one that reflects the reality of globalization, another innovation enabler that is considered next.

Friedman [2005] has captured the globalization phenomenon in a catchy phrase: the world is flat, implying that the competitive playing field has been flattened so that anyone can innovate without having to emigrate to the U. S. He astutely recognizes 10 events or forces that all came together in the 1990s and converged around the year 2000. They include: 1) 11/9/89, the day the Berlin Wall came down and the world became one; 2) 8/9/95, the day Netscape went public and ushered in the global potential of the Internet with a concomitant over-investment (and subsequent dot-com bubble and crash) in optic fibers, an investment which greatly benefited India's weak infrastructure; 3) out-sourcing, whereby support work – especially software-writing – can be digitized, disaggregated and shifted to any place in the world (e.g., India) where it could be done cheaper, better and faster; 4) off-shoring, whereby entire factories are shipped overseas (e.g., to China) because of cost considerations; 5) open-sourcing, whereby software source codes are shared and improved by interested users; 6) in-sourcing, whereby one company allows another company (e.g., United Parcel Service) to take over, for example, its logistics operation; 7) supply-chaining, whereby an efficient global supply chain links, for example, Wal-Mart to all its suppliers in real-time; 8) informing, whereby anyone can access data and information through the various search engines; 9) wireless access, whereby anyone can be reached at anytime and from anyplace; and 10) Voice over Internet Protocol (VoIP), whereby telephony is carried out over the Internet. It should be noted that flatteners 3 through 8 are actually different forms of collaboration. In order to counter the adverse impacts of a flat world on the U. S., he recommends that three U.S. versus China/India gaps have to be addressed: an ambition gap among our workers, a production gap of graduating engineers and scientists, and an education gap in our K-12 grades.

There is also a serious age gap between the so called developed (i.e., Europe and North America) and developing (i.e., Asia and Latin America) countries of the world. As summarized in Table 2-4, while all the world's population (except for Africa) is aging at an alarming rate, by 2050 the developed countries will only have about 2 working age persons per age 65 or older person and the comparable figure for the developing countries is almost 4. Additionally and barring large-scale immigration and dramatic changes in retirement policies, the demand for services by the retired and the elderly will be particularly acute in Europe and North America, where coincidentally the economies are primarily services-oriented. Thus, it is critical that services innovation be significantly enhanced so that the quality of life will not diminish in today's economically advanced, services-oriented nations (including Japan where only about 1.5 workers will support a retiree in 2050). However, Dychtwald et al. [2006] suggest that companies can mitigate the impact of boomer generation retirement by redefining retirement and transforming management and human resource practices to attract, accommodate, and retain skilled workers of all ages and backgrounds.

Table 2-4. Global Demographics

Regions	**Percent of Population Aged 60 or Older**		**Working Age Persons Per Age 65 or Older Person**	
	2002	**2050**	**2002**	**2050**
Europe	20.0%	37.0%	3.9	1.8
North America	15.7%	27.1%	5.0	2.8
Asia	8.6%	22.9%	11.1	3.9
Latin America	7.9%	22.1%	11.0	3.8
Africa	5.0%	10.0%	16.8	8.9

Source: *United Nations*, 2002 Population Data

Another interesting consequence of the flat world is the emergence of a "stateless", 24/7 (i.e., always-on) transnational enterprise. For example, Trend Micro, an antivirus software company with executives and laboratories spread out in seven locations throughout the world from Munich to Tokyo, has been able to react and respond to viruses faster than Symantec, the market leader. With dual headquarters in Switzerland and Silicon Valley and its manufacturing center in low-cost Taiwan and China, Logitech is able to compete effectively with Microsoft in the area of computer peripherals. Wipro, a technical services supplier with headquarters in both India and Silicon Valley, is becoming a vendor of choice because it can adaptively deploy its 20,000 India-based software engineers and consultants, as needed. To mitigate the differences in time zones and cultures, transnational companies communicate in real-time over the Internet, via e-mail, through instant messenger or by Web videoconferencing.

3. SERVICES SECTOR

The importance of the services sector can not be overstated; it employs a large and growing proportion of workers in the industrialized nations. As reflected in Table 2-5, the services sector includes a number of large industries; indeed, services employment in the U.S. is at 82.1 percent, while the remaining four economic sectors (i.e., manufacturing, construction, agriculture, and mining), which together can be considered to be the "goods" sector, employ the remaining 21.4 percent. In practice, the delineation between the different economic sectors are blurred; this is especially true between the manufacturing and services sectors, which are highly interdependent [Tien and Berg, 1995; Berg et al., 2001].

Clearly, the manufacturing sector provides critical products (e.g., autos, computers, aircrafts, telecommunications equipment, etc.) that enable the delivery of efficient and high-quality services; equally clear, the services sector provides critical services (e.g., financial, transportation, design, supply chain, etc.) that enable the production, distribution and consumption of effective and high-quality products. Moreover, such traditional manufacturing powerhouses like GE and IBM have become more vertically integrated and are now earning an increasingly larger share of their income and profit through their services operation. For example, in 2005, IBM's pre-tax income was $12.2B (based on a total revenue stream of $91.1B) and it was divided into three parts: 28 percent from computer systems, 37 percent from software, and 35 percent from information technology services and consulting. Thus, IBM earned 28 and 72 percent of its profits from goods and services, respectively; as a result, IBM no longer considers itself a computer company anymore – instead, it offers itself as a globally integrated innovation partner, one which is able to integrate expertise across industries, business processes and technologies.

Table 2-5. Scope and Size of U.S. Employment

Industries	Employment (M)	Percent
Trade, Transportation & Utilities	26.1M	19.0%
Professional & Business	17.2	12.6
Health Care	14.8	10.8
Leisure & Hospitality	13.0	9.5
Education	13.0	9.5
Government (Except Education)	11.7	8.5
Finance, Insurance & Real Estate	8.3	6.1
Information & Telecommunication	3.1	2.2
Other	5.4	3.9
SERVICES SECTOR	**112.6**	**82.1**
Manufacturing	14.3	10.3
Construction	7.5	5.5
Agriculture	2.2	1.6
Mining	0.7	0.5
GOODS SECTOR	**24.7**	**17.9**
TOTAL	**137.3**	**100.0**

Source: *Bureau of Labor Statistics*, April 2006

What constitutes the services sector? It can be considered "to include all economic activities whose output is not a physical product or construction, is generally consumed at the time it is produced and provides added value in forms (such as convenience, amusement, timeliness, comfort or health) that are essentially intangible..." [Quinn et al., 1987]. Implicit in this definition is the recognition that services production and services delivery are so integrated that they can be considered to be a single, combined stage in the services value chain, whereas the goods sector has a value chain that includes supplier, manufacturer, assembler, retailer, and customer. More specifically, as indicated in Section 2, services are co-produced, whereas goods have traditionally been pre-produced; this and other differences between services and goods are explored in Section 5 to identify possible innovations in services. Tien and Berg [2003] provide a comparison between the goods and services sectors. The goods sector requires material as input, is physical in nature, involves the customer at the design stage, and employs mostly quantitative measures to assess its performance. On the other hand, the services sector requires information as input, is virtual in nature, involves the customer at the production/delivery stage, and employs mostly qualitative measures to assess its performance. Since services are to a large extent subject to customer satisfaction and since, as Tien and Cahn [1981] postulated and validated, "satisfaction is a function of expectation," service performance or satisfaction can be enhanced through the effective "management" of expectation. Parasuraman et al. [1998] employed the gap between expectation and actual service to evaluate service quality, as defined by reliability, tangibles, assurance, responsiveness and empathy.

Tien and Berg [2003] also call for viewing services as systems that require integration with other systems and processes, over both time and space; in fact, they make a case for further developing a branch of systems engineering that focuses on problems and issues which arise in the services sector. In this manner, they demonstrate how the traditional systems approach to analysis, control and optimization can be applied to a system of systems that are each within the province of a distinct service provider. They underscore this special focus not only because of the size and importance of the services sector but also because of the unique opportunities that systems engineering can exploit in the design and joint production and delivery of services. In particular, a number of service systems engineering methods are identified to enhance the design and production/delivery of services, especially taking advantage of the unique features that characterize services – namely, services, especially emerging e(lectronic)-services, are decision-driven, information-based, customer-centric, computationally-intensive, and productivity-focused.

As we consider the future, it is perhaps more appropriate to focus on emerging e-services. E-services are, of course, totally dependent on information technology; they include, as examples, financial services, banking, airline reservation systems, and customer goods marketing. The introduction of the Universal Product Code (UPC) and the optical scanning of these codes have not only, for example, shortened checkout times but also yielded critical data for undertaking marketing research. Furthermore, the UPC has been critical to the coupling of the production and logistics stages in the supply chain. Additional e-services are based on the Global Positioning System (GPS), which is bringing significant productivity improvements to the world's transportation and emergency service (i.e., police, ambulance and fire) agencies, as well as to other dispatch-oriented industries (e.g., taxicab companies, delivery services, and maintenance services). Of course, the Internet is the world's data superhighway in which businesses can interact with their far-flung offices, or with other businesses; customers can buy goods and services; and individuals can exchange e-mails or surf for information. Despite the "dot-com bubble" burst in the early 2000s, the Internet is flourishing and e-services or e-commerce is continuing to grow.

As indicated in Table 2-6, the electronic service enterprises interact or "co-produce" with their customers in a digital (including voice mail, e-mail, and Internet) medium, as compared to the physical environment in which the traditional or bricks-and-mortar service enterprises interact with their customers. Similarly, in comparison to traditional services which include low-wage jobs, the electronic services typically employ high-wage earners – and they are more demanding in their requirements for self-service, transaction speed, and computation.

Table 2-6. Comparison of Traditional and Electronic Services

	SERVICE ENTERPRISES	
ISSUE	**TRADITIONAL**	**ELECTRONIC**
Co-Production Medium	Physical	Electronic
Labor Requirement	High	Low
Wage Level	Low	High
Self-Service Requirement	Low	High
Transaction Speed Requirement	Low	High
Computation Requirement	Medium	High
Data Sources	Multiple Homogeneous	Multiple Non-Homogeneous
Driver	Data-Driven	Information-Driven
Data Availability/Accuracy	Poor	Rich
Information Availability/Accuracy	Poor	Poor
Size	Economies of Scale	Economies of Expertise
Service Flexibility	Standard	Adaptive
Focus	Mass Production	Mass Customization
Decision Time Frame	Predetermined	Real-Time

In regard to data sources that could be used to help make appropriate service decisions, both sets of services rely on multiple data sources; however, the traditional services are primarily based on homogeneous (mostly quantitative) data, while the electronic services could require non-homogeneous (i.e., both quantitative and qualitative) data. Paradoxically, the traditional service enterprises have been driven by data, although data availability and accuracy have been limited (especially before the pervasive use of the UPC); likewise, the emerging e-service enterprises have been driven by information (i.e., processed data), although information availability and accuracy have been limited, again due to the aforementioned data rich, information poor (DRIP) conundrum. Consequently, while traditional services – like traditional manufacturing – are based on economies of scale and a standardized approach, electronic services – like electronic manufacturing – emphasize economies of expertise or knowledge and an adaptive approach. The result is a shift in focus from mass production to mass customization (whereby a service is produced and delivered in response to a customer's stated or imputed needs); it is intended to provide superior value to customers by meeting their unique needs. It is in this area of customization – where customer involvement is not only at the goods design stage but also at the manufacturing or production stage – that services and manufacturing are merging in concept. Another critical distinction between traditional and electronic services is that, although all services require decisions to be made, the former services are primarily based on predetermined decision rules, while the latter could require more real-time, adaptive decisions; that is why Tien [2003] has advanced a decision informatics paradigm that relies on both information and decision technologies from a real-time perspective.

Increasingly, customers want more than just traditional or electronic services; they are seeking experiences [Pine and Gilmore, 1999]. Customers walk around with their iPods, drink their coffee at Starbucks while listening to and downloading music, dine at such theme restaurants as the Hard Rock Cafe or Planet Hollywood, shop at such experiential destinations as Universal CityWalk in Los Angeles or Beursplien in Rotterdam, lose themselves in such virtual worlds as Second Life or World of Warcraft, and vacation at such theme parks as Disney World or the Dubai Ski Dome, all venues that stage a feast of engaging sensations that are provided by an integrated set of services and products or goods. There is, nevertheless, a distinction between services and experiences; a service includes a set of intangible activities carried out for the customer, whereas an experience engages the customer in a personal, memorable and holistic manner, one that tries to engage all of the customer's senses. Obviously, experiences have always been at the heart of entertainment, from plays and concerts to movies and television shows; however, the number of entertainment options has exploded with digitization and the Internet. Today, there is a vast array of new experiences, including interactive games, World Wide Web sites, motion-based simulators, 3D movies and virtual reality. Interestingly, the question may be asked: just as electronic services have accelerated the commoditization of goods, will experiences accelerate the commoditization of services?

In the previous section, we consider innovation enablers; in this section we consider services, in particular electronic services. It is now helpful to consider services innovation in terms of the pertinent enablers, the underpinning technologies and the underlying decision attributes. In particular, Table 2-7 lists seven of the nine enablers (all except decision informatics and software algorithms) and identifies chips, software, and information technologies as being able to facilitate, if not effect, the enablers of automation, telecommunication, collaboration, standardization, customization, organization, and globalization; in addition, sensor, Internet, wireless, cognition, visualization, collaboration, telecommunication and management technologies are required for some of these enablers. In regard to decision attributes, it is seen that all except two service innovation enablers (i.e., standardization and organization) require a i) decision-driven, ii) information-based, iii) real-time, iv) continuously-adaptive, v) customer-centric and vi) computationally-intensive approach; for obvious reasons, standardization and organization do not require a real-time focus. All six decision attributes are within the decision informatics paradigm that is considered next.

Table 2-7. Services Innovation: Enablers, Technologies and Decision Attributes

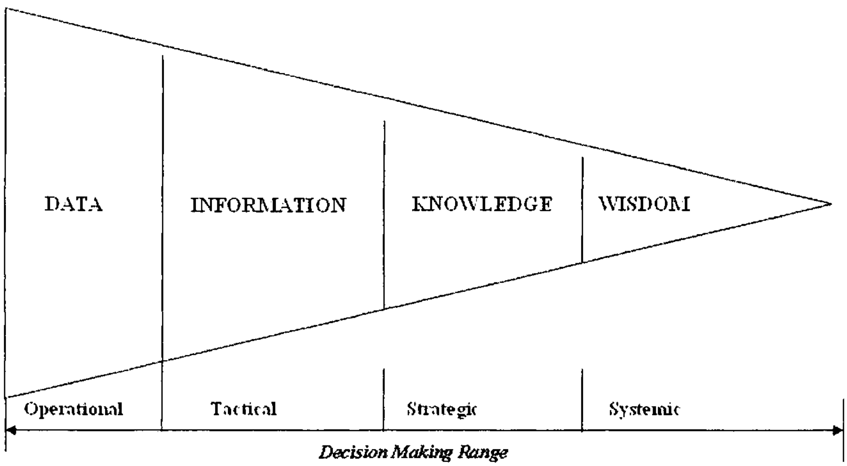
Enablers	**Underpinning Technologies**	**Underlying Decision Attributes***					
		DD	**IB**	**RT**	**CA**	**CC**	**CI**
Automation	Chips; Software; Information; Sensor	✔	✔	✔	✔	✔	✔
Telecommunication	Chips; Software; Information; Internet; Wireless; Sensor	✔	✔	✔	✔	✔	✔
Collaboration	Chips; Software; Information; Cognition; Visualization	✔	✔	✔	✔	✔	✔
Standardization	Chips; Software; Information; Collaboration	✔	✔		✔	✔	✔
Customization	Chips; Software; Information; Telecommunication	✔	✔	✔	✔	✔	✔
Organization	Chips; Software; Information; Telecommunication; Management	✔	✔		✔	✔	✔
Globalization	Chips; Software; Information; Telecommunication; Collaboration	✔	✔	✔	✔	✔	✔

*DD (Decision-Driven), IB (Information-Based), RT (Real-Time), CA (Continuously-Adaptive), CC (Customer-Centric), CI (Computationally-Intensive)

4. DECISION INFORMATICS

Before discussing decision informatics [Tien, 2003], it is helpful to highlight the difference between data and information, especially from a decision making perspective. As shown in Table 2-8, data represent basic transactions captured during operations, while information represents processed data (e.g., derivations, groupings, patterns, etc.). Clearly, except for simple operational decisions, decision making at the tactical or higher levels requires, at a minimum, appropriate information or processed data.

Table 2-8. Decision Making Framework



(a) Decision Levels

Basis	**Decision Considerations**
• Data	Basic observations; measurements, transactions, etc.
• Information	Processed data; derivations, groupings, patterns, etc.
• Knowledge	Processed information plus experiences, beliefs, values, culture; explicit, tacit/conscious, unconscious.
• Wisdom	Processed knowledge plus insight and assessment over time and space; theories, etc.

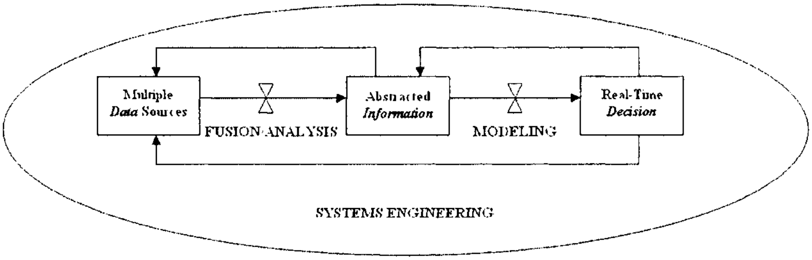
(b) Decision Bases

Table 2-8 also identifies knowledge as processed information (together with experiences, beliefs, values, cultures, etc.), and wisdom as processed knowledge (together with insights, theories, etc.). In our vernacular, strategic decisions can only be made with knowledge, while systemic decisions can only be made with wisdom. Although the literature sometimes does not distinguish between data and information, it is critical to do so, especially if we wish to avoid the data-rich, information-poor (DRIP) conundrum that is identified in Section 1. In fact, if we were to strictly adhere to such a distinction, we would conclude that given the current state of information technology, it should be referred to as "data technology" and, as indicated in Section 1, we are not in a knowledge – but only a data – economy.

A decision informatics approach is needed not only to develop new innovations in services (especially e-services and/or experiences) but also, if appropriate, to be packaged within a software algorithm that can serve to automate – and thereby enhance the productivity of – the developed innovation. As depicted in Table 2-9(a), the nature of the required real-time decision (regarding the production and/or delivery of a service) determines, where appropriate and from a systems engineering perspective, the data to be collected (possibly, from multiple, non-homogeneous sources) and the real-time fusion/analysis to be undertaken to obtain the needed information for input to the modeling effort which, in turn, provides the knowledge to identify and support the required decision in a timely manner. The feedback loops in Table 2-9(a) are within the context of systems engineering; they serve to refine the analysis and modeling steps. As depicted in Table 2-9(b), the driving force behind decision informatics is the decision foci. In regard to services innovation, the decisions concern how best to a) collaborate (especially in regard to self-serving, contributing, communicating, standardizing and globalizing issues), b) customize (especially in regard to profiling and personalizing issues), c) integrate (especially in regard to supply chaining, demand chaining, data warehousing and systematizing issues), and d) adapt (especially in regard to real-timing, automating, organizing and motivating issues). Actually, collaboration, customization, integration, and adaptation may be considered to be the four major drivers for services innovation; that is, services are promulgated in order to further collaboration, customization, integration and adaptation. Not surprisingly, the four services innovation drivers somewhat overlap the nine innovation enablers that are described in Sections 1 and 2; in fact, collaboration and customization are at once both drivers and enablers for services innovation.

More specifically, decision informatics is supported by two sets of technologies (i.e., information and decision technologies) and underpinned by three disciplines: data fusion/analysis, decision modeling and systems engineering. Data fusion and analysis methods concern the mining, visualization and management of data, information and knowledge; they include statistics, mathematics, management science and cognitive science. However, from the perspective of services innovation, it should be noted that

Table 2- 9. A Decision Informatics Paradigm



(a) Paradigm

Disciplinary Core	Related Methods
Decision Foci (For Services Innovation)	• Collaboration: self-serving, contributing, communicating, networking, standardizing, globalizing • Customization: profiling, personalizing • Integration: supply chaining, demand chaining, data warehousing, systematizing • Adaptation: real-timing, automating, organizing, motivating
Data Fusion/Analysis	• Statistics: non-homogeneous data fusion, fuzzy logic, neural networks, biometrics • Mathematics: probability, classification, clustering, association, sequencing • Management Science: expectation management, yield management • Cognitive Science: visualization, cognition
Decision Modeling	• Operations Research: optimization, simulation, prediction • Decision Science: game theory, risk analysis, dynamic pricing, Bayesian networks • Computer Science: service-oriented architecture (SoA), XML, genetic algorithms • Industrial Engineering: project management, scheduling,
Systems Engineering	• Electrical Engineering: cybernetics, networks, pattern recognition • Human Machine Systems: human factors, cognitive ergonomics, ethnography • System Performance: life-cycle, value chain • System Biology: predictive medicine, preventive medicine, personalized medicine

(b) Methods

the available data fusion and analysis methods suffer from two critical shortcomings. First, the available methods are predominantly focused on quantitative data, which is, of course, very limiting since it is estimated that over 80 percent of the available data are qualitative in nature. Second, the available methods are primarily focused, if not trained, on a fixed data set, whereas in the real-world, there is a constant stream of data that require continuous fusion and analysis. Clearly, methods must be developed that can fuse and analyze a steady stream of non-homogeneous (i.e., quantitative and qualitative) data.

It is helpful to further address data fusion, which can take place at the signal level, the feature level and/or the decision level. Signal-level fusion refers to combining the signals of a group of sensors. The signals from the sensors can be modeled as random variables, contaminated by uncorrelated noise. The fusion process is considered an estimation procedure. Only if the sensory signals are strictly homogeneous or alike can the fusion take place at the signal level. Feature-level fusion refers to combining the features that are extracted from sensory data. A set or vector of primary features is first obtained, then composite features can be created, and analysis is typically undertaken on the composite features. Thus, Ayache and Faugeras [1989] use extended Kalman filtering to efficiently integrate sequences of images at the feature-level in order to determine the surfaces of three-dimensional objects. The feature-level fusion enables the overall uncertainty concerning the location of objects to be reduced in the presence of environmental and sensory noise. Gunatilaka and Baertlein [2001] extract geographic features by nonlinear optimization techniques, and then they determine whether a certain type of mine is located in the region by applying Bayesian decision theory to the composite features.On the other hand, decision-level fusion refers to combining information extracted from sensory data at the highest level of abstraction; it is commonly employed in applications where multiple sensors are of a different nature or are located in different regions of the environment. Fusion is accomplished by judicious processing of the individual sensory information, or through symbolic reasoning that may make use of prior knowledge from a world model or sources external to the system. The prevailing techniques for decision- or symbol-level fusion include Bayesian (i.e., maximum a posteriori) estimation [Gunatilaka and Baertlein, 2001] and Dempster-Shafer evidential reasoning [Garvey et al., 1981]. Evidential reasoning is actually an extension of the Bayesian approach; it makes explicit any lack of information concerning a proposition's uncertainty by separating firm belief for the proposition from just its plausibility. In the Bayesian approach, all propositions (e.g., objects in the environment) for which there are no information are assigned an equal a priori probability. When additional information from a sensor becomes available and the number of unknown propositions is large relative to the number of known propositions, an intuitively unsatisfying result of the Bayesian approach is that the probabilities of known propositions become unstable. In the Dempster-Shafer approach, this is avoided by not assuming an a priori probability. Instead, the unknown propositions are assigned to "ignorance", which is reduced only when supporting information becomes available. Evidential reasoning is introduced to allow each sensor to contribute information at its own level of detail. For example, one sensor may be able to provide information that can be used to distinguish individual objects, whereas the information from another sensor may only be able to distinguish classes of objects.

Decision modeling methods concern the information-based modeling and analysis of alternative decision scenarios; they include operations research, decision science, computer science and industrial engineering. Likewise, decision modeling methods suffer from two shortcomings. First, most of the available – especially optimization – methods are only applicable in a steady state environment, whereas in the real-world, all systems are in transition. (Note that steady state, like average, is an analytical concept that allows for a tractable, if not manageable, analysis.) Second, most of the available methods are unable to cope with changing circumstances; instead, we need methods that are adaptive so that decisions can be made in real-time. Thus, non steady-state and adaptive decision methods are required. More importantly, real-time decision modeling is not just about speeding up the models and solution algorithms; it, like real-time data fusion and analysis, also requires additional research and development.

Systems engineering methods concern the integration of people, processes, products and operations from a systems perspective; they include electrical engineering, human-machine systems, systems performance and systems biology. Again, the real-time nature of co-producing services – especially human-centered services that are computationally-intensive and intelligence-oriented – requires a real-time, systems engineering approach. Ethnography, a branch of anthropology that can help identify a consumer's unmet needs, is being used to spot breakthrough product and service innovations; as examples, it is being credited with developing a Motorola cell phone that allows text messaging using Chinese characters, a portable Sirius satellite-radio player, and a PayPass tag that provides Citigroup customers with a debit service. Another critical aspect of systems engineering is system performance; it provides an essential framework for assessing the decisions made – in terms of such issues as satisfaction, convenience, privacy, security, equity, quality, productivity, safety and reliability. Similarly, undertaking systems engineering within a real-time environment will require additional thought and research.

The decision informatics paradigm can be very appropriately employed to develop new approaches or innovations. Two such example innovations are summarized in Table 2-10. The first was an NSF-funded effort, entitled, "Automated Discovery of Novel Pharmaceuticals," in which Embrechts et al. [2000] focus on identifying novel candidate pharmaceuticals. Molecular

Table 2-10. Innovation Examples Using Decision Informatics

FOCUS	DRUG DISCOVERY EXAMPLE	AGILE MANUFACTURING EXAMPLE
Effort	"Automated Discovery of Novel Pharmaceuticals" (NSF, $1.2M, 9/99-8/02); a bioinformatics application.	"Electronic Agile Manufacturing Research Institute" (NSF/Industry, $11.2M, 4/94-8/00); a distributed manufacturing approach to circuit board design and assembly, resulting in a patent and a new incubator company called "ve-design.com".
Decision	Molecules that could be novel drug candidates.	Design, fabrication and assembly of a printed circuit board.
Data Fusion/Analysis	Molecular data are analyzed and information is derived concerning some 1000 descriptors for each molecule.	Based on possible design configurations, software or intelligent "agents" obtain relevant cost and cycle time information from the vast data sets resident in computers of possible suppliers (Cisco, Pitney Bowes, Lucent, Rockwell Automation).
Decision Modeling	Obtained information is input into various neural network and genetic algorithm models to determine those qualitative structural activity relationships that might be of interest or yield improved bio-activities.	Obtained information is input into a genetic algorithm model that assists in deciding the best design (in terms of components, supplies, geometries, technologies).
Systems Engineering	Entire process is to be automated, employing a systems framework that includes returning the non-selected molecules to the information base for further processing.	Entire virtual design environment is developed to operate in a network of distributed databases/alternative designs resident with members of supply chain.

data are analyzed and information is obtained concerning some 1000 descriptors for each molecule; based on various neural network and genetic algorithm models, the quantitative structural activity relationships (QSARs) are determined to help screen and decide on those molecules which could be candidate drugs due to their interesting or improved bioactivities. The entire process is automated, employing a systems engineering framework that includes returning the non-selected molecules to the information base for further QSAR analysis, screening and selection.

In the second example, Graves et al. [1999] completed another NSF-funded effort, entitled, "Electronic Agile Manufacturing," with a focus on the design of a printed circuit-board assembly (PCBA). Cost and cycle time data in design, fabrication, and assembly are statistically analyzed to yield a networked information environment of relationships between PCBA characteristics and their effect on cost and cycle time; these relationships are, in turn, input into a genetic algorithm model that helps the designer to decide on the best PCBA design (in terms of components, suppliers, geometries and technologies) from literally thousands of possible alternatives. The entire virtual design environment is systems engineered to operate in a network of distributed databases and alternative designs, resident at and maintained by members of a supply chain. An automated, real-time information prototype has been developed and tested, employing real design files and data from collaborating companies, including Cisco Systems, Pitney Bowes, Rockwell Automation and Lucent Technologies.

Yet a third example of applying the decision informatics paradigm is in the context of major urban disruptions [Tien, 2005]. Urban infrastructures are the focus of terrorist acts because, quite simply, they produce the most visible impact, if not casualties. While terrorist acts are the most insidious and onerous of all disruptions, it is obvious that there are many similarities in the way one should deal with these willful acts and those caused by natural and accidental incidents that have also resulted in adverse and severe consequences. However, there is one major and critical difference between terrorist acts and the other types of disruptions: the terrorist acts are willful – and therefore also adaptive. One must counter these acts with the same, if not more sophisticated, willful, adaptive and informed approach. Real-time, information-based decision making (i.e., decision informatics) is the approach that can be employed to make the right decisions at the right time in the various stages of a disruption. As discussed above, it is focused on decisions and based on multiple data sources, data fusion and analysis methods, timely information, stochastic decision models and a systems engineering outlook. The approach provides a consistent way to address real-time emergency issues, including those concerned with the preparation for a major disruption, the prediction of such a disruption, the prevention or mitigation of the disruption, the detection of the disruption, the response to the disruption, and the recovery steps that are necessary to adequately, if not fully, recuperate from the disruption. As a consequence, we must trade off between productivity and security; between just-in-time interdependencies and just-in-case inventories; and between high-probability, low-risk life-as-usual situations and low-probability, high-risk catastrophes.

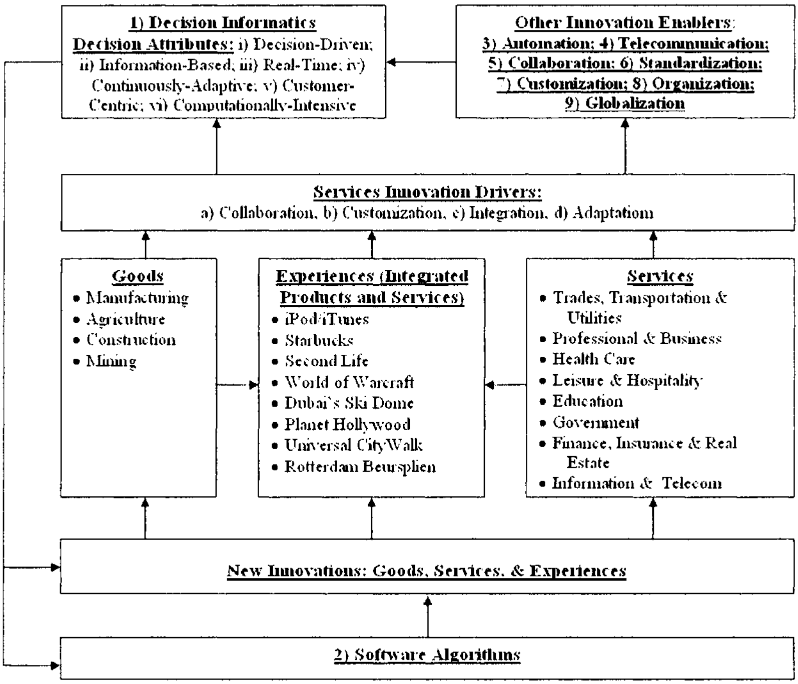
Finally, it should be noted that decision informatics is, as a framework, generic and applicable to most, if not all, decision problems. Actually, it is likewise applicable to any design problem, inasmuch as the essence of design is about making decisions concerning alternative scenarios or designs. (Not surprisingly, innovation is sometimes characterized as "design thinking".) Additionally, since any data analysis, modeling or design effort should only be undertaken for some purpose or decision, all analyses, modeling and design activities should be able to be viewed within the decision informatics framework, including the development of new decision-theoretic tools that can integrate sensed data in support of real-time decision making. In short, decision informatics represents a decision-driven, information-based, real-time, continuously-adaptive, customer-centric and computationally-intensive approach to intelligent decision making by humans and/or software agents. Consequently, it can be very appropriately employed to address decisions regarding the design and delivery of innovative services; it is a necessary tool for or enabler of services innovation.

5. SERVICES INNOVATION

Sections 1 through 4 have, in essence, defined a process for undertaking services innovation. Table 2-11 provides a summary of the process. It identifies the relationships between goods, services and experiences (which are typically integrated products and services); shows how the nine enablers and four drivers interact to yield new innovations in goods, services and experiences; and highlights why decision informatics is a necessary enabler. As noted earlier, decision informatics constitutes a pivotal step in developing or deciding on a new services innovation; additionally, it is, if appropriate, central to (i.e., the brain in) any software algorithm that can serve to automate – and thereby enhance the productivity of – the developed innovation. As we focus on services innovation, it is helpful to reexamine the four innovation drivers: collaboration, customization, integration and adaptation. All four are directed at empowering the individual – that is, at recognizing that the individual can a) contribute in a collaborative situation,

b) receive customized or personalized attention, c) access an integrated system or process, and d) obtain adaptive real-time or just-in-time input.

Table 2-11. Services Innovation: Drivers, Enablers and Decision Attributes



Nevertheless, the question remains: where are the areas or white spaces for possible new innovations in services (and/or experiences)? The answer can be found by considering the nine innovation enablers (described in Section 1 and 2), the six services-related decision attributes (identified in Section 3), and the four services innovation drivers (discussed in Section 4); their coverage serve to identify the potential white spaces. As examples, Table 2-12 identifies the primary drivers, enablers and decision attributes associated with 45 services innovation areas, assuming 5 in each of the 9 service categories or domains. Although both the domain areas and the identification process are quite subjective, it is interesting to note that the drivers, in order of impact, are: integration (16 out of 45), adaptation (13), customization (12), and collaboration (4). Similarly, the enablers are:

automation (19), organization (7), globalization (5), customization (5), standardization (5), telecommunication (2), and collaboration (2). (Inasmuch as decision informatics and software algorithms are somewhat pervasive and pertinent to all areas, only 7 of the 9 enablers are considered.)

Although Table 2-12 lists the existent innovations in the 45 areas, there is considerable room for many more innovations in these same areas. As examples, with sophisticated wireless and global positioning technologies, highway commuters should be able to put their cars on autopilot; with multimedia and wideband technologies, entire degree programs with just-in-time learning capabilities should be able to be accessed online [Tien, 2000]; and with real-time customized management of both the supply and demand chains, a jacket, for example, should be able to be personalized (in size, color and style) and produced in a matter of hours [Tien et al., 2004; Gershenfeld, 2005].

Indeed, the services landscape is full of white spaces. Paradoxically, one set of white spaces concern innovations that can mitigate the unforeseen consequences or abuses of earlier innovations. Antivirus companies like Symantec and Trend Micro are barely able to cope with the avalanche of new viruses and virus delivery schemes. Ad spamming is taking over the email system, much like junk mail took over the traditional postal system. Spyware, a form of adware that tracks an individual's every click and sends the data to advertisers, has now infected some 80 percent of all personal computers in the U. S. Indeed, fraudulent clicks by robotic viruses have cost advertisers millions of dollars. In "phishing" or creating a replica of an existing Web page to fool users into submitting personal, financial or password data, hackers are stealing individual identities and committing fraud. Sadly, the same innovations that have enhanced global interconnectedness have engendered new vulnerabilities, including cyber attacks. Thus, electronic viruses, biological agents and other toxic materials can turn a nation's "lifelines" into "deathlines", in that they can be used to facilitate the spread of these materials – whether by accident or by willful act. In this vein, the Internet – with over a billion users – has become a terrorist tool; jihad websites are recruiting members, soliciting funds, and promoting violence (e.g., by showing the beheading of hostages). Also, as evidenced by the 9/11 attack, components of an infrastructure (e.g., airplanes) can be used as weapons of destruction. In sum, new and more powerful innovations are required to secure and safeguard those innovations – including mobile devices, electronic systems, and, more recently, even RFID tags – that define and underpin our advanced economies.

A related set of white spaces concern innovations that can safeguard our rights to privacy. In fact, in 2003 the U. S. Congress stopped the Terrorism Information Awareness program sponsored by the Department of Advanced

Table 2-12. Services Innovation and Decision Informatics

Example Innovations			**Decision Attributes***					
Service Categories **Trade, Transportation & Utilities**	**Primary Driver**	**Primary Enabler**	**D D**	**I B**	**R T**	**C A**	**C C**	**C I**
Trading (eBay, Green Energy Tags, E-Waste Recycling)	Collaboration	Standardization	✔	✔	✔	✔	✔	✔
RFID (Supply Chain, Automated Checkout, P&G, Wal-Mart)	Customization	Automation	✔	✔	✔	✔	✔	✔
Travel Sites (Expedia, Orbitz, Travelocity, Travelzoo, Priceline)	Integration	Globalization	✔	✔	✔	✔	✔	✔
Intelligent Transportation Systems (Interoperability, Standards)	Integration	Standardization	✔	✔	✔	✔	✔	✔
Payment Systems (PayPal/eBay, Peppercoin, Paystone, BitPass)	Adaptation	Automation	✔	✔	✔	✔	✔	✔
Professional & Business								
Web Commerce (Amazon, Wal-Mart, ToysRUs)	Integration	Globalization	✔	✔	✔	✔	✔	✔
Real-Time Routing (JetBlue, UPS, FedEx, BostonCoach)	Adaptation	Customization	✔	✔	✔	✔	✔	✔
GPS-Based Services (Traffic, Emergencies, Local Info)	Adaptation	Customization	✔	✔	✔	✔	✔	✔
Targeted Marketing (Amazon, Harrah's, BMW, Wells Fargo)	Adaptation	Customization	✔	✔	✔	✔	✔	✔
Business Processes (Textron's Streamlining, Nucor's Incentives)	Adaptation	Organization	✔	✔	✔	✔	✔	✔
Health Care								
E-Health (Imaging, Diagnostic AmpliChips)	Customization	Automation	✔	✔	✔	✔	✔	✔
Bionic Parts (Limbs, Heart, Lungs, Liver, Eyes, Ears)	Customization	Automation	✔	✔	✔	✔	✔	✔
Health Reform (Mandatory Insurance, Digital Records)	Customization	Standardization	✔	✔	✔	✔	✔	✔
One-Stop Wellness Facility (Medical, Dental, Spa, Therapy)	Customization	Organization	✔	✔	✔	✔	✔	✔
Bioinformatics (Drugs, Genomics, Proteomics, Glycomics)	Adaptation	Automation	✔	✔	✔	✔	✔	✔

Leisure & Hospitality								
Social Networking (MySpace, Craigslist, Visible Path)	Customization	Collaboration	✔	✔	✔	✔	✔	✔
Retail Tourism (Mall of America)	Customization	Organization	✔	✔	✔	✔	✔	✔
Experiential Venues (Starbucks, ESPN Zones, IMAX Theatres)	Customization	Organization	✔	✔	✔	✔	✔	✔
Virtual Environments (Second Life, World of Warcraft)	Customization	Collaboration	✔	✔	✔	✔	✔	✔
Simulated Environments (Dubai's Ski Dome)	Customization	Organization	✔	✔	✔	✔	✔	✔
Education								
Smart Games (Sudoku, Brain Age, Big Brain Academy, IQ)	Adaptation	Automation	✔	✔	✔	✔	✔	✔
New Foci (Services Science, Innovation Engineering)	Integration	Organization	✔	✔	✔	✔	✔	✔
Online Degrees (U. of Phoenix, EArmyU, Florida Virtual School)	Adaptation	Globalization	✔	✔	✔	✔	✔	✔
E-Training (Certifications, Microsoft, Cisco, Kinko)	Adaptation	Globalization	✔	✔	✔	✔	✔	✔
E-Reference (WebMD, FindLaw, Wikipedia)	Integration	Automation	✔	✔	✔	✔	✔	✔
Government								
Imaging (Airport Screening, Target Tracking, Predator Drone)	Integration	Automation	✔	✔	✔	✔	✔	✔
Security (CAPPS II, Biometrics, Coplink, Relationships Ident)	Integration	Automation	✔	✔	✔	✔	✔	✔
Research (GPS Profiling, WMD Sensing)	Integration	Automation	✔	✔	✔	✔	✔	✔
Civil Service (Motivation, Morale, Retention, Recruitment)	Adaptation	Organization	✔	✔	✔	✔	✔	✔
National Counterterrorism Center (Email, Voice, Databases)	Integration	Automation	✔	✔	✔	✔	✔	✔
Finance, Insurance & Real Estate								
Credit Ratings (TransUnion, Equifax, Experian)	Integration	Automation	✔	✔	✔	✔	✔	✔
Web Trading (Schwab,	Integration	Automation	✔	✔	✔	✔	✔	✔

Fidelity, TD Ameritrade, ETFs)								
Web Realty (zipRealty, HomeGain, LendingTree, Zillow)	Integration	Automation	✔	✔	✔	✔	✔	✔
Web Insurance (Insweb, Progressive's Auto, Aon's TechShield)	Integration	Automation	✔	✔	✔	✔	✔	✔
Wealth Care Investments (Portfolios Reflecting Life and Living)	Integration	Automation	✔	✔	✔	✔	✔	✔
Information & Telecom								
Web Search (Google, Yahoo, AOL, MSN, Windows Live)	Integration	Customization	✔	✔	✔	✔	✔	✔
Voice Over Internet (Vonage, Skype, Comcast, Time Warner)	Collaboration	Telecomm.	✔	✔	✔	✔	✔	✔
Content Collaboration (Wikipedia, YouTube, Flickr)	Integration	Globalization	✔	✔	✔	✔	✔	✔
Software Collaboration (Red Hat, JBoss, MySQL)	Collaboration	Automation	✔	✔	✔	✔	✔	✔
Advanced Mobile Devices (PDAs, Satellite Radio, OnStar Autos)	Collaboration	Telecomm.	✔	✔	✔	✔	✔	✔
Other								
Assemble-to-Order (BMW, Dell, Whirlpool, FreshDirect)	Adaptation	Standardization	✔	✔	✔	✔	✔	✔
Made-to-Order (Siemen's Hearing Aids, Fab Labs)	Adaptation	Automation	✔	✔	✔	✔	✔	✔
On-Demand (IBM, Microsoft Dynamics, Accenture)	Adaptation	Customization	✔	✔	✔	✔	✔	✔
E-Advertising (Display Banners, Search Ads/Clicks, Productions)	Customization	Automation	✔	✔	✔	✔	✔	✔
Brand Marketing (Tide, Always, Pampers, iPod, Intel Inside)	Customization	Standardization	✔	✔	✔	✔	✔	✔
*DD (Decision-Driven), IB (Information-Based), RT (Real-Time), CA (Continuously-Adaptive), CC (Customer-Centric), CI (Computationally-Intensive)								

Research Projects Agency (DARPA) because it was going to mine massive amounts of data, including personal transactions of U. S. citizens, in order to connect the dots leading to terrorists and terrorism. Moreover, the continuing anti-terrorist surveillance program by the U. S. government and the widely acclaimed and increasingly profitable search, marketing and even social networking innovations on the Internet could easily be considered to be an invasion of privacy. As an example, constitutional scholars feel that current wiretapping by the National Security Agency (NSA) on communications between individuals outside the U. S. and citizens inside the country is both unconstitutional and against the 1978 Foreign Intelligence Surveillance Act (FISA). Additionally, identifying one's buying habits, broadcasting one's location and submitting data to social network sites about one's friends (without their explicit permission) are also questionable from a privacy perspective. Clearly, sophisticated innovations are required to prevent incursions into our private lives.

Another set of white spaces concern innovations that can protect us from the always-on, interconnected world. With a 24/7 electronic world and wireless mobile devices, we are unfortunately always reachable – for mostly business purposes – from anywhere in the world. Increasingly, our business life extends into and takes over or displaces our home life. Thus, although our work output has increased (mostly due to our increased working hours), we are not necessarily more productive. Furthermore, as Surowiecki [2005] suggests, more electronic devices and gadgets do not necessarily increase our well-being; instead, over time, we tend to take these innovations for granted and to raise our expectations for what future innovations can bring, thus mitigating our overall satisfaction – which, as Tien and Cahn [1981] confirmed, is a function of our expectation. Hallowell [2006] argues that the 24/7 frenzy has drained us of creativity, humanity, mental well-being, and the ability to focus on what truly matters – we suffer from a culturally induced attention deficit disorder. He suggests that we can teach ourselves to move from the F-state (i.e., frenzied, flailing, fearful, forgetful, and furious) to the C-state (i.e., cool, calm, clear, consistent, curious, and courteous). Nevertheless, new innovations are required to protect ourselves from the F-state.

Yet another white space for services innovation is the development of an authoritative search engine. At present, for example, Google provides a weighted or prioritized set of output pages when a word or phrase search is initiated; unfortunately, several hundreds of pages are presented and sometimes with conflicting, if not confusing, information – a classic case of the aforementioned data rich, information poor (DRIP) conundrum. Likewise, Wikipedia – with an anyone-can-contribute ethos and a 200 gigabyte database, containing 3 million articles in 200 languages – suffers from the same problem, even though some contributions can be deleted by a Wikipedia elite of some 800 longtime contributors. Interestingly, in a recent comparison between Wikipedia and its major peer, Encyclopedia Britannica, *Nature* [2005] asked experts from several disciplines to review 50 articles – with identical subject matter and of similar length – from each encyclopedia and assess them for their accuracy, resulting in 2.9 errors per article for Encyclopaedia Britannica versus 3.9 errors per article for Wikipedia. Nevertheless, it is obvious that an authoritative Google (Agoogle) is needed, one which provides fewer pages of output and a higher degree of accuracy for each search. Such an Agoogle would not only replace the various search engines but may well become the largest capitalized company in the world.

A final white space concerns the economic measurement of services itself. Corrado et al. [2005] are concerned that while the government's decades-old system of data collection and statistical analysis are appropriate for capturing tangible investments in equipment, buildings and even software, they are inadequate in reflecting the growing knowledge economy, one driven by intangible ideas and services innovation. In other words, the Bureau of Economic Analysis in Washington, D. C., is not tracking the billions of dollars that companies spend each year on innovation and product design, brand-building, employee training, or any of the other investments – not consumption costs – that are required to compete in today's global economy. As a result, services-oriented economies – like those of the U. S. and Japan – are probably much stronger than the official statistics indicate. Such a measurement innovation may result in a "knowledge-adjusted" GDP metric.

6. CONCLUDING REMARKS

In conclusion, several remarks should be made. First, it should be stated that although so called, "business intelligence" (BI) software (offered by MicroStrategy, Hyperion Solutions, SAS, Cognos, etc.) could have been developed by employing the decision informatics paradigm that is advanced herein, we are not aware that any of the proprietary software actually followed such a purposeful, systematic and decision-driven approach. Moreover, to our knowledge, most of the BI software attempts to make sense of the transactions data and to present it in a way that anyone, from a sales representative to a chief executive, can understand and use; indeed, for the most part, the software represents a query window into data warehouses. Thus, it is unclear whether the BI software contains any sophisticated, real-time data fusion, data analysis, decision modeling, or systems engineering methods.

Second, as emphasized throughout this paper, significant research is required to fully and fruitfully apply the proposed real-time, information-based approach to services innovation. Indeed, the decision informatics paradigm must continuously undergo upgrades and refinements, especially as computing becomes faster and cheaper and as powerful new tools are developed. For example, research into cognition (i.e., understanding how people process input) could result in findings that may have a significant impact on not only services innovation, but also the decision making process itself.

Third, as real-time decisions must be made in an accelerated manner, the human decision maker or service provider will increasingly become a bottleneck; he/she must make way for a smart robot or software agent. For example, everyone could use a smart alter ego or agent which could analyze, and perhaps fuse, all the existing and incoming e-mails, phone calls, Web pages, news clips, and stock quotes, and assigns every item a priority based on the individual's preferences and observed behavior. It should be able to perform a semantic analysis of a message text, judge the sender-recipient relationships by examining an organizational chart and recall the urgency of the recipient's responses to previous messages from the same sender. To this, it might add information gathered by watching the user via a video camera or by scrutinizing his/her calendar. Most probably, such an agent would be based on a Bayesian statistical model – capable of evaluating hundreds of user-related factors linked by probabilities, causes and effects in a vast web of contingent outcomes – that infers the likelihood that a given decision on the software's part would lead to the user's desired outcome. The ultimate goal is to judge when the user can safely be interrupted, with what kind of message, and via which device. Perhaps the same agent could serve as a travel agent by searching the Internet and gathering all the relevant information about airline schedules and hotel prices, and, with the user's consent, returning with the electronic tickets. Clearly, such innovative agents can be developed by employing the decision informatics paradigm.

Finally, the decision attributes, innovation enablers and innovation drivers advanced in this paper provide an effective calculus for identifying, developing and promulgating services innovation. Thus, the paper serves as a critical step towards understanding the science, management and engineering of services.

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