INFORMATION SYSTEMS

THE CONNECTION OF PEOPLE AND RESOURCES FOR INNOVATION

Cheng Hsu

Department of Industrial and Systems Engineering

Rensselaer Polytechnic Institute

Troy, New York 12180-3590

Final Draft

August 26, 2011

World Scientific Publishers

PREFACE

This book is written for serious students of Information Systems (IS). The author intends to provide a concise textbook on system analysis and database design that covers a range of deep knowledge integrated from the field. However, the author also strives to develop new thinking on the science and practice of IS for a knowledge economy. In particular, we ask: what does the "connected world" mean, and how can we design IS in such a world? An answer is developed by ***combining the emerging network science and service science with classic IS results***.

One would say, why bother? Indeed, IS design is a mature field. The literature is full of commercially available techniques and tools for IS strategic planning and industry-proven models of structured system analysis. As for databases, an enormous body of knowledge has been accumulated over past decades. It is just that a great deal of change has taken place in the world since the pioneering works of, e.g., Gordon and Olson 1974/1981. For example, the age of corporate mainframe computers has given way to one of person-centered digital connections and computing. We are witnessing the convergence of social networking and business; customers and providers; and physical world and cyberspace. The time may have come for the field to take another fresh look into "the concepts, structure, and development" of IS as its pioneers did.

The author is always fascinated by how quickly we the people innovate on the Internet, such as finding new ways to network and promote our causes. It is also marvelous to see obscure entrepreneurs inventing new business designs and thereby surpassing long-established conglomerates in market valuation. However, what fascinates the author most, from an academic perspective, is the pivotal role that IS plays in all these innovations – connecting people and resources to make them happen. The flip side of the coin is that the field does not seem to have been credited fully either by the science community or by the general public. When such progress as e-commerce first came about, people credited them to Information Technology (IT) and asked about the intellectual nature of such IT-induced revolution, in the face of the by-then already matured discipline of IS. The author was amazed, and dismayed, by the obvious lack of recognition for IS.

In hind sight, the field should have done a better job on incorporating IT into IS, to show that IS brings about serendipity; IS spawns innovation; and IS enables this knowledge economy. Then, the field should explain why the key to understanding the future is to understand IS. Instead of building this big picture, many IS textbooks virtually reduced the science of IS to mere anecdotes of IT, and treated students as casual readers. This book is an attempt propelled by these lessons to move forward, and focuses on designing IS for innovation.

The intellectual roots of innovation may be found in the seminal works by economist Joseph A. Schumpeter, who described capitalism as the perennial gales of creative destruction and attributed economic growth to innovations (Capitalism, Socialism, and Democracy 1942). One can safely argue that the stories of e-commerce and information revolution are testaments to Schumpeter's thesis. However, the author further argues that these stories are actually stories of IS: innovation by IS and IS innovation. An e-commerce site is an IS; a social networking site is an IS; and the Web itself is an IS, too. An enterprise inventory system is an IS; a global supply chain where the participants are digitally connected with each other is an IS; and all these IS form systems of IS on the basis of societal cyber-infrastructure. Furthermore, information systems never die, they just reincarnate in the world of systems of IS. When the world is increasingly connected, the world becomes a system of IS, as well. Where is IS design science heading in such a world?

This book suggests a simple theme: the perennial gales of creative destruction in the 21st century will see IS renovating the networking of people and resources to bestow new values on the digitally connected society. That is, it starts with ***a connectionist definition of IS***: *the networking of IS Elements (people, processes, information resources, computing platform, and communications infrastructure) in the connected world for value creation.* Then, in accordance, it builds the IS design science on the analysis of IS elements; networking for value creation; and the analytic properties of the connected world.

This definition reflects the profound progress in the IS field since the pioneers' time. It establishes that the immediate scope of an IS can be the world, a domain, an enterprise, a person's life, or just a particular job. Information systems bring about innovation by enabling new value propositions, new connections, and new IS elements; and hence they should be designed as such. The new thinking of IS in this book is embodied in the principles for strategic planning, which are based on the core concept of human value networks (Chapters 1 – 3). These principles are linked to the standard results of structured system analysis and database design in the field (Chapters 4 – 7).

The first chapter develops the basic concepts that support the connectionist definition of IS, and calibrates them on the empirical evidence in the field. It identifies the economic concept of transaction cost and the engineering concept of cycle time to be the underpinnings of the basic values of IS, and shows that an IS is a human value network from the perspective of service science. On this basis, it explains the evolution of IS. Finally, it presents the new concepts of sustainable IS and societal cyber-infrastructure to show how the notion of systems of IS gives a unique perspective to the connected world.

Chapter 2 establishes the relationship between network science and information systems and thereby develops generic strategies of innovation by IS. After reviewing the basic discoveries of network science such as the scale-free propensities and the small world phenomena, it analyzes e-commerce business designs to show that their novelty is really due to new thinking in human value networking. A hyper-networking model is then presented to capture the analytic nature of the human value networks. This analysis leads to a set of strategies for developing IS visions; i.e., IS strategic planning.

Chapter 3 is devoted to IS engineering (master plans): providing guidelines and roadmaps for determining the overall architecture of IS and the scope of IS elements. This chapter uses a design scenario of hyper-networking alumni and their alma mater to lead the discussion. Design methodologies, along with industrial examples, are provided for the digitization of IS elements; information integration within an enterprise; and collaboration across an extended enterprise. It also analyzes how societal cyber-infrastructure can add value to IS. This chapter concludes with certain IS design principles for service enterprises.

The above three chapters represent the new theory of IS that this book presents. The next four chapters synthesizes standard IS design results in the literature. The particular presentation of these materials in this book reflects the author's many years of experience teaching them to students at all levels and applying them to real world projects. Some analysis and guidelines in these chapters are unique contributions of this book.

Chapter 4 is concerned with process modeling, or structured system analysis for determining the specific IS elements required according to the IS master plan. This book elects to focus on an original method, the data flow diagram (DFD), since it captures the essence of process modeling and encompasses the basic logic of many other methods. This method is fully illustrated with modeling guidelines and examples to help the reader apply it for actual work.

Chapter 5 presents a succinct and yet practical review of architectural designs on the whole range of databases, from PC systems to Internet systems. The concept of systems of IS is substantiated in this chapter by the review. A baseline database model is first built on the classic three-schema design, whose ensuing extensions explain the evolution of information integration from standalone enterprises to extended enterprises. As such, the prototypical distributed environments of data warehouses, federated databases, and custom designs are presented in a uniform treatment, to ready the reader for further exploration into the emerging challenges of massive numbers of independent databases on the Internet. Some experimental but lab-proven design ideas are also introduced for connecting global information resources.

Chapter 6 deepens the coverage of database design from the level of architectures in Chapter 5 to the level of data modeling and data normalization. It reviews the paradigms of relation,Entity-Relation-Attribute (ERA), and Object-Orientation (O-O), from the perspective of their common driving force: the need to consolidate enterprise data resources in the presence of differential user requirements for them. This chapter covers data normalization to the level of Boyce-Codd normal form, and includes the unified modeling language (UML) in data modeling. A particular experimental design of Chapter 5 is further developed here.

Chapter 7 presents the de facto standard database language in the world today: the ANSI SQL (Structured Query Language), and shows how it may be extended to support global query of Internet databases, in a systems-of-IS manner. This chapter starts with relational algebra and calculus, and moves progressively to the data definitional part and the data manipulation part of SQL. It also reviews some prototypical design ideas (e.g., XQUERY and Metadatabase) for extending SQL to achieve global query of multiple databases on the Internet.

Chapter 8 brings this book from the SQL level of details back to the level of IS strategic planning. It focuses on IS innovation by convergence of physical environment and cyberspace. A real world case (the I87 Northway Corridor in New York State, USA) is analyzed here to show how the concept of hyper-networking people and resources can generate IS visions to help renovate regional economy. This chapter concentrates the analysis of innovation on highway administration, personal safety, tourism, intelligent network flows, and global logistics. It represents a substantiation of the basic IS principles developed in the first three chapters.

The conclusion of this book is provided in Chapter 9. Several student projects from the author's past classes which have applied the materials in this book to real world IS problems are presented first. This chapter then moves to contemplate on the role of IS in continuing innovation in a knowledge economy. It interprets the notion of hyper-networking people and resources via IS in terms of microeconomics, especially production functions, to show the significance of IS in a knowledge economy.

Most chapters have incorporated exercises in their discussion to help illustrate the abstract concepts that they develop. These exercises are joined with many classroom examples and industrial cases which are developed by the author based on his past teaching and research. In addition, Chapter 5 reconstructs the classic three-schema design and the federated schema design from the literature; and Chapters 6 and 7 also include a few tables inspired by some examples in Atre (1980) and Date (2004). These original sources have been credited in the appropriate places. The author wishes to acknowledge generally all the textbooks that he has consulted for teaching; which are too numerous to mention individually here (see bibliography).

On this note, the author wishes to thank his many colleagues and former students, whose participation in his career has made this book possible. The TSER and Metadatabase work has contributed significantly to Chapters 5 – 7. Although proper credit and citations to the work have been included where appropriate, the author still wishes to express his inexhaustible gratitude to all his former advisees and research associates. Special thanks are due to Drs. Laurie Rattner Schatzberg, M'hamed Bouziane, Lester Yee, Waiman Cheung, Gilbert Babin, Yi-Cheng Tao, Jangha Cho, Somendra Pant, Veera Boonjing, and David Levermore; and Mr. Alvaro Perry and Mr. Otto Schaefer. It is indeed the author's fortune to have had the chance of working with these outstanding talents. This book has also incorporated results that the author published in co-authored papers with other colleagues. In addition to the citations given in the text, the author wishes to expressly recognize Dr. James Spohrer of IBM for work on the concept of DCS; Dr. Victor Chen for work on the mathematical properties of hyper-networking; and Dr. William (Al) Wallace for work on verifying the Northway Corridor messages. Both Victor and Al are close colleagues at Rensselaer. Furthermore, the author wishes to thank his professors during the formative years of his career: Professors Wilpen Gorr, William Cooper, and Prabuddha De; who enlightened him on information, systems, and information systems. Numerous other colleagues, students, and friends have participated in the author's experience of teaching and research, which went into this book. Some are recognized in Section 9.1 of Chapter 9, but most would remain to be thanked only in the author's private thought due to the limitation of space here. Finally, the author happily recognizes his daughter, Diana, for helping proofread the manuscript.

The field of Information Systems has come of age. The author's academic career has also come of age. This book presents a tribute to both.

CHAPTER 1

INFORMATION SYSTEMS: THE SCIENCE AND PRACTICE OF CONNECTING PEOPLE AND RESOURCES TO CREATE VALUE

The whole Web is an information system. The individual Web sites are information systems. The digital applications in offices, factories, and universities are information systems. The smartphones with apps are information systems, too. Less tangibly, a supply chain is an information system. The organization of any enterprise is also an information system; and so is the market mechanism of the economy. Information systems have enabled agile manufacturing, e-commerce, and social networking over the past few decades; and they promise to continue spawning innovations in our knowledge economy. So, what is the design science of Information System (IS) for the 21st century? This book synthesizes proven results from the field with contemporary research and presents a reference point from this ***innovation*** perspective: IS seeks to ***network*** five types of Information System Elements: people (users), process (application software/analytics), information resources (digital storage), computing (digital devices), and communications infrastructure (networks), for value creation in the ***connected*** world. The scope could be global, or for a domain, for an enterprise, for a person's life, or just for a particular job. This chapter develops a cohesive set of information system principles, which constitute a basic ***connectionist theory of information systems***. The basic values of IS, recent history of IS evolution, and the collective life of systems of IS in the connected world are also studied.

1.1 The Connectionist Definition of Information System

The term "information system" has become a part of our daily lingo. It first appeared in the academic lexicon during 1970-80's, when computer applications became commonplace in the economy and society. The significance was that people recognized that computers were playing a much larger role than computing per se. These two words, information and system, separately had a very long history in human languages before they were bonded into one. In fact, the separate journeys of these two words and their evolution into one may have heralded the progress of modern civilization. We do not intend to define these two words away from each other, other than acknowledging that many theories have existed for decades in the attempt to explain what is information (see, e.g., Claude E. Shannon 1949 and John von Neumann 1956) and what is system (see, e.g., Abram Charnes and William W. Cooper 1961). We just use them according to the common sense. However, we do ask, what is "information system (IS)"? Clearly, the answer must be more than just a "system of information".

Here, competing definitions exist (see, e.g., the many IS textbooks), each of which exerts profound ramifications on the theory, design, and performance of information systems in actuality. Instead of providing a critical review of the field, which does not serve the cause of this book, we humbly accept all definitions that make sense in the myriad practices of the field. Yes, inventory systems, online banking systems, Google, Facebook, and all the specimens that someone calls information systems are indeed information systems. We just ask how to capture the ***unique*** nature of IS in our ***connected*** world, so as to foster its growth into the future.

Yes, the premium is on the understanding of the word ***connected***. An information system is connected, of course, as everyone agrees; but is it also always connected to other information systems in the world in some way? Should this nature of connection be deliberately recognized, analyzed, and fostered in the design of IS? For example, if an IS never dies, but just reincarnates, because some of its elements (including analytics and data resources) may last indefinitely, then should the design science of IS consider sustainability? If the IS supports enterprises in a "flat world", then should the design be flat, too? If the Web is pervasive, then should the design take advantage of this pervasiveness? If the IS represents an innovation for the economy, then should the design foster the innovation of business designs, enterprising, and inter-person collaboration in return, to help sustain the economy's eternal pursuit of better and more value creation?

If the IS connects, then exactly what does it connect, what for, what to sustain or expand if the IS grows, and how? Where do IS visions come from, and how does one recognize the inherent logic of the planning, analysis, design, development, and control of the connecting IS? The long journey of developing an answer starts with recognizing the common and basic Information System Elements from all application domains – i.e., identifying the core value propositions for all IS applications and postulating a connectionist theory of IS from them. This book embraces the service science worldview (Hsu 2009) as the starting point: scaling IS up to support the (enterprise in the) global economy; down to facilitate individuals' tasks (as a knowledge worker or a person); and transformationally to enable new business designs and mode of production. This chapter then calibrates the theory on the history of IS since 1970-80's, and review its continuing evolution. The following is a short list of the basic Information System Elements that this book recognizes:

Basic Information System Elements

Person: the user of IS. In the automated version of IS, users could be machines such as some software agents or application systems. This element may include dedicated security, interface, and embedded tools for interaction with each other as well as with other IS elements. Although users tend to proprietarily defined, they can also be open such as in the case of a Web site, or cover both the customers and knowledge workers of the enterprise as well as IS professionals.

Process: the enterprise processes (analytics, functions and applications) and IS controls. They include analytics, tools, and application software for or of the IS tasks, such as the digital processing of information resources (production factors), the embodiment/implementation of the process of value creation, and the interaction of the persons (customers and knowledge workers) with the processes with security control. Collectively, they are the software/process users of the information resources. This element enacts on the IS and turn it into actions for its mission.

Information Resources: the sharable data, knowledge (rules, heuristics, cases, etc.) and other information resources. They also include repositories of digital representation of persons, processes, and other physical production factors, and the standards and protocols that define them (e.g., ontology and embedded intelligence, business component models, and Modelbase). Software programs in and of themselves are a form of information resources, too, when they are not running, and in the sense that they can be accumulated, shared, and reused like others do.

Computing: the digital platform (hardware) on which the IS executes. This category includes computer of any class, personal digital devices such as cell phone, and any other physical information technology (IT) components that constitute the computing capacity of the IS. The tasks of the platform encompass the processing and storage of processes and information resources, connection of persons to the infrastructure, and connection of this computing capacity to shared external facilities providing utilities of computing to the IS.

Communications Infrastructure: the (digital) platform for connection within and without the IS. It includes networks of any scale, telecommunications (wired or wireless), and (built-in) protocols and network management systems that connect computing elements and administer the infrastructure. Typically, a significant IS nowadays deploys and employs the Internet and other public cyber-infrastructure as well as proprietary enterprise cyber-infrastructure to connect the IS elements. Often, third party vendors also provide (parts of) the infrastructure.

The last four classes of IS elements may also be collectively referred to as simply the IS resources. The classes of processes and information resources include the usual representation data about physical resources such as raw materials, buildings, and civil infrastructure. However, since physical resources could also be augmented by digital devices (e.g., sensors and computing chips - see Chapter 8), this book broadly incorporates such “digitization” of the physical resources in the scope of IS. Therefore, we say that an IS connects people and resources.

We note that an IS enterprise may not be able to, or at least not need to, proprietarily own every IS element that it uses. Rather, they may deploy and employ open source technology and/or public cyber-infrastructure resources to fulfill their needs. This approach may actually be preferred if the IS requires openness and scalability to operate across multiple organizations.

The connectionist view recognizes that an enterprise possesses rich IS elements, of course. However, it trains the vision on the fact that society possesses an enormous repository of these IS elements, too, from which any IS can potentially draw for its use. That is, all the IS elements from all information systems, private or public, have the potential, and indeed the promise, to become assets capable of being used by any other IS anywhere, new or existing. The question is only to make the connection: what, why, and how. Proprietary rights and controls are the common constraints to connection between information systems of different ownership, while the (lack of) openness and scalability of IS elements involved often are the inhibitors to the connection of information systems of the same ownership. The concern for cyber-security presents one more deterrence to pursuing systems of IS – the more connected, the more exposed. Overcoming such barriers is a predicate to innovation by IS. Indeed, deliberate effort here promises to lead to powerful new business value propositions and scientific progress in the IS field. Without making any value assertion, we point out that this connectionist definition of IS is amenable to the ideal of "one for all and all for one" in a connected world.

EXERCISES

1. Please analyze what are the IS elements for the whole Web?
2. Suggest what may be the possible IS elements for Google, Amazon.com, and Netflix.
3. Pick an information system from your organization, or any organization that you know, and specify its IS elements as definitively as you can (e.g., a student information system).
4. Define an IS by connecting Facebook, Twitter, Google, and some other IS on the Web: first state what are the IS elements and what is the purpose of the IS (the value of the connection); and then recognize the particular IS elements from these systems that you need to connect for your IS.
5. Search the Internet to find some open source technologies that you may use to make the connection envisioned/required in (4) above. Hint: visit apache.org, php.net, mysql.com, omg.org, oasis.org, alice.org, and locate some sources for VBA applications, SQL based database triggers (in, e.g., PL/SQL), and Web services (mobile objects).
6. Discuss some possible new business designs (paradigm shifting changes) on the Internet, along the general idea of making the Web a more cohesive IS to support personal and organizational life cycle tasks (e.g., one-stop buying, selling, and managing).

One can go as deeply as one wish to do the above six exercises. Here, we offer some basic ideas. Looking at the Web as whole, this IS is rich in information, but sporadic in transactions and lacking in cohesive decision support. Its security and integrity control are ad hoc at best, but its user interface and infrastructure are sustainably open and scalable. In particular, the Web IS includes the following well-known elements:

- Person: everyone that has access to the Internet, with the common user interface being the homepages (or, the HTTP protocols).
- Process: mainly search engines, functions at Web access providers (proprietary and public domain protocols), and all application software at individual Web sites.
- Information Resources: all the contents of individual Web sites (or, all the homepages, documents available at Web sites, and open source software and technologies).
- Computing: all the hardware at the disposal of all users and individual Web sites.

- Infrastructure: the Internet (protocols and hardware) and the proprietary networks at the individual Web sites and user sites.

Google obviously has specific and proprietary IS elements, such as the (soft agents) processes for acquiring Web contents from the globe, their onsite repositories of Web contents, and the arrays of computing and communications technologies. However, their proprietary IS elements are deliberately integrated with the public domain practices and systems. In general this observation applies to all other Internet enterprises including Netflix, Amazon.com, Facebook, and Twitter, too. Processes for online products (e.g., calendars and geographical directions at Google), social networking (e.g., "following" at Facebook and Twitter), and promotion of products (e.g., clustering of customers and products for online recommendations at Netflix and Amazon.com) are of course the hallmarks of these powerful Web information systems. Their information resources are largely obvious: (digitized) books, movies, and members' homepages. However, the customer information they acquired, including the digital trails of the member activities at their sites, may represent the most innovative part of the strategic advantages that these Internet enterprises enjoy over their traditional counterparts (if any).

In fact, the Internet has prompted many open source communities as generic IS elements that any enterprises can use to develop their proprietary IS, as well as providers of solutions using such open source technology. The famous PHP-Apache-MySQL alliance is one visible example, and the popular Wikipedia is another. One can readily develop complex enterprise IS from these open source technology and solutions, with or without common proprietary software. An entire software industry has been founded on doing this. Numerous open source technologies and solutions are available from the Web and industry giants such as IBM have embraced them to complement proprietary technology and solution providers. The so-called Web services, SaaS (software as a service), and consortia of consulting firms (e.g., OASIS.org) are well-known examples. Although the line separating non-profit from for profit is thin in the field, one could safely argue that new open source contributors are emerging and joining forces throughout the Internet in a spirit of something other than making a buck. On the other hand, hackers represent the dark and often destructive side of the same coin of this individuality on the Internet. We would rather look positively and call the spirit of open sources "one for all and all for one".

The sixth question, concerning new business designs on the Internet, begs a review of the short but nonetheless unprecedentedly explosive history of e-commerce since the late 1990's. This book devotes the next chapter to this review. Here, we simply comment that many new business designs can fall under a generic umbrella of connections provider: to assemble IS elements and facilitate their (on-demand) connections for performing (customized) life cycle tasks. The notion of cloud computing actually describes an important aspect of this connection: providing computing as an IS element to connect to other IS elements for value creation applications. If one borrows the proprietary branding due to Apple, then the connections providers may be branded as iIS, iWeb, and the like, following iPod, iPhone, iPad, and iCloud.

An intriguing perspective is for one to sit back and imagine, either as a person going about his/her private life, or as a professional undertaking some job assignments, or both: how s/he may wish to use the future Web as her/his personal IS, or working in seamless sync with the proprietary systems at work. This is the best way to contemplate the sixth exercise suggested above. We submit that IS has seen scaling up from individual functions and applications such as inventory control to enterprise-wide such as enterprise resources planning, and now to extended enterprises such as the IBM notion of Globally Integrated Enterprises and Smarter Planet. This evolution clearly reflects on the extension and expansion of connections of IS elements, and even the inter-connection of different information systems, in the pursuit of ever inter-connected value propositions in the connected world.

The path may just lead IS to such a point of iWeb. The technology has also been opened up from purely proprietary to public domain. Thus, a next step in the form of ***cyber-infrastructure-enabled, Web-embedding, and person-centered IS*** may not be so outlandish but in fact quite natural and even inevitable. This concept of IS does not exclude the traditional form of proprietary, function-oriented IS, but rather extend and expand it for the global economy. In this inclusive and evolutionary sense, we embrace it as the full scope of the connection for IS.

Thus, we provide the following ***connectionist definition of IS*** as consummation to the above discussion:

Information Systems *is the networking of IS Elements (people, processes, information resources, computing platform, and communications infrastructure) for value creation in the connected world. Its immediate scope can be the world, a domain, an enterprise, a person's life, or just a particular job. Information systems bring about innovation by enabling new value propositions, new connections, and new IS elements.*

A ***corollary*** is the innovative nature of such connections in IS: the connections enable new value propositions among persons, facilitated by new access to (new) resources (non-person elements).

A second ***corollary*** is concerned with the design of IS: an IS should be cyber-infrastructure-enabled, Web-embedded, and person-centered, to maximize the benefits of connections.

Next, we turn to the phrase "value creation".

1.2 The Basic Values of Information System: reduction of transaction cost and cycle time

The field has been struggling to find the most accurate ways to measure the performance of an IS and assess its value (e.g., payoffs and return on investment) ever since the IS profession formed. We are content in this book to establish the basic, generic values that an IS is expressly poised to produce: the ***reduction of transaction costs and cycle times***. Please note that one may develop IS to create particular values such as providing decision information to certain management processes, or pursue particular value propositions such as enabling specific innovative information products to sell to customers. The IS value in these cases may be broad and even abstract, unlike the values in straightforward automation or computerization, which often take the form of labor saving. However, it is these forms of value that innovative IS aims to create for all kinds of users. The point is that both levels of value, and indeed all forms of value that IS creates, are reducible to the same fact of reducing transaction costs and cycle time.

Just consider a simple example: searching for someone on the Web. If doing so without the Web is hard because it is difficult to get to identify the various sources of information and even more difficult to gain access to and comb through the sources, then the basic value of the Web as an IS is its savings on reducing the transaction cost and cycle time that made the search without the Web hard. Thus, in general, if the IS makes it easier or possible to obtain certain information or achieve some higher degree of precision of information and thereby facilitates or enables the job, then the root cause of the value to the job is the reduction of transaction cost and cycle time associated with obtaining such information without the IS. Labor savings in straightforward IS applications, such as automation, are traceable to the same reductions, too.

Incidentally, these generic values offer a way to uniformly measure the returns from intangible benefits as well as tangible ones. When both values are accounted for and included into the usual methods of valuation such as return on investment (ROI), then firms may be able to more accurately measure the contributions of their IS investment. The so-called "productivity paradox" of late 1990's and early 2000's is an illustration of the need for this kind of uniform measures. The economy back then did not register much productivity gains from the astronomical investment on information technology (IT), at a time when the whole society was witnessing an IT-driving transformation of the economy. The gap between the evidence and the perception of IT contributions was puzzling. Obviously, the way of "registration" has serious flaws in it. Later, researchers were able to dispute the assertions from other data and measures.

We wish to point out here that transaction cost and cycle time are not the same thing: the former is primarily operation-based, while the latter primarily process-based. One may reduce the cycle time of a job by reducing its transactions involved, such as answering a query or performing a search; but one may also reducing the cycle time by increasing the transactions. An example is concurrent processing of a sequential job, as in office workflows. An IS that supports concurrent processing typically can reduce the cycle time at the expense of increased processing due to control or other coordination and monitoring.

EXERCISES

1. In many places, soft drinks are sold with a deposit on the bottle (say, a nickel or 5 cents), which can be redeemed at designated places when the bottles are returned. Then, why in those places may bottles still litter the ground or fill trash cans, while few nickels receive the same treatment – i.e., why people might throw away bottles but not nickels?

2. How would one measure the value of an IS to a professional who can use the IS to get information which otherwise, without the IS, would require making a number of phone calls or other forms of research to obtain?
3. What is the (inherent) transaction cost associated with buying or selling a house?
4. If a project requires 1,000 man-hours to complete, then what is the minimum labor that the project requires to complete it in one hour?
5. Office workflows typically involve a series of tasks, and some common examples are found in job interviews and business proposal review. Suggest some general IS design principles to make the IS an enabler for turning a sequential workflow into concurrent and thereby reducing its overall cycle time. (Hint: think connection.)
6. How to measure the value of cycle time reduction?
7. If one (e.g., the Nobel Laureate in Economic Science, Herbert A. Simon) considers a human organization to be an "information processor" for facilitating data handling, information exchange, and decision making among all the stakeholders to discharge their common missions, then the organization is a transactions processor, too. Can this view be generalized to explain economics?
8. What role IS may play in the transaction cost view of economics?

Some of the answers are plainly obvious. Considering the first question: Turning a nickel into currency that one can spend right away, anyway, requires zero transaction cost, while doing this to a bottle involves considerable ***transaction cost*** (taking it to the right place for exchange, handling it to get credit, and making the credit an unrestricted currency). In other words, transaction costs, albeit abstract compared to traditional price tags, are every bit as tangible and for real as the traditional cost: it means people losing real money in this case.

The second question shows that transaction cost is often translated, or valuated, into time whose monetary value, in turn, is measurable by wages and the like. How much time the professional in question usually spent on acquiring the information that the IS provided, and how much money this amount of time is worth to the company? Equally measurable, directly, is the monetary worth of the "red tape" involved in any transactions: how much one is willing to pay for someone else to do it for him/her? All the buyers and sellers pay to all the brokers and agents involved reflect on the minimum cash equivalent of the transaction cost of the house sale process (plus that the buyers and sellers pay for themselves).

Clearly, one thousand men working simultaneously is the minimum requirement for finishing a 1,000 man-hour job in one hour, since more men may be needed to coordinate among all simultaneous tasks. The (unique) role of IS in this enterprise, therefore, is equally clearly to be the facilitation of this concurrent processing: making this possible through the connection of persons to (information) resources required in the coordination and execution of the simultaneous tasking. This is simply the connectionist definition of IS. A common database shared by all persons (generalists or specialists) to support their respective tasks makes the connection, and hence will spell out the design principles for the enabling IS. We shall come back to this point in great details in later chapters.

The value of ***cycle time*** reduction manifests itself in the same way as transaction cost reduction does, of course. However, it also arises from quality of service and quantity of production (productivity); both of which determine the competitiveness of an enterprise. It is worthwhile to note that the quality to customers may translate into avoidance of lost sales (e.g., customers balking due to long wait) as well as attracting additional customers. Although not all such measures are readily available to an enterprise, they nonetheless are not infeasible to quantify, either. We submit that even conservative implementation of some measures for the reduction of transaction cost and cycle time due to the deployment and employment of an IS promises greatly enhance the accuracy of the ROI and other traditional methods.

The last two questions actually represent the high end vision of the connectionist definition of IS in a connected world. The short answer to the seventh question is yes, as found in the concept of ***organizational transaction cost*** - see Williamson (1985). This school of thought, continuing in a sense the so-called Carnegie-Mellon School of Barnard, Simon, March, and Cyert, theorizes that firms came into being as an optimization of organizational transaction cost for economic enterprises. In this worldview, on the one hand, societal institutions including laws represent some mechanism of regulation of common transactions costs for all; and, on the other hand, an organization is an embodiment of processes that transact (producing, exchanging, and transforming) on information to accomplish the organization's goals. The interesting point is that this abstract concept of organizational information processing is "visualized" in and by IS; i.e., an IS is not only a tool for societal or organizational information processing, but also a realization of the organization. Therefore, the IS contributions to the enterprise processes are contributions to the organization as an information processor, and ultimately contributions to the (micro)-economy to which the firms are the foundations.

The big picture here is the simple fact that transaction cost is a scalable concept connecting the whole economy together from the minute level of redeeming a bottle to the level of economic value chain optimization and societal welfare. Just imagine how much more difficult it would make our daily lives if the society is lawless – i.e., how much more transaction cost at all levels it would cause us at every turn of going about life. Therefore, transaction costs do reflect the efficiency, effectiveness, and welfare for persons, organizations, and the society. In this picture, IS deals directly with transaction costs at all levels as the scope of its connection of IS elements scaling up or down across persons and organizations. Therefore, the ultimate characterization of the IS contributions to the economy is by evaluating its contributions to (damping the transaction costs in) the micro-economic production functions; and furthermore by recognizing its role in technological innovation (e.g., new capacity, efficiency, and value chains) and how the innovation uplifts the overall economic performance. This book does not develop this line of analysis, but is content with the long accomplishments of this line of thought starting from, e.g., Joseph Schumpeter (1945), whose work is the theoretical foundation to results in Chapter 9. For convenience, at the enterprise level, we measure the IS contributions to organization transaction cost in terms of the reduction to the total transaction cost and cycle time; which in turn are a function of the individual processes' transaction costs and cycle times.

If transaction cost is activity based, and hence generic to any economic enterprises, then cycle time is evidently process-based and more amenable to system design – i.e., it is concerned with the engineering question of how to connect activities. Enterprise cycle times such as the time to market for new product development and the throughput (service or physical) of a factory are subject of intensive studies in engineering and management. Common design principles include simplification (removing transactions), integration (removing non-value-added connections), and concurrency (removing idleness). Examples include agile manufacturing, concurrent (simultaneous) engineering, and supply chain integration. All these enterprises rely heavily on innovative IS designs, which in turn rely on innovating the way IS elements are connected: simplifying them, integrating them, and sharing and reconfiguring them. The design of connections also determines the relationship between transaction cost and cycle time. If a cycle consists only of sequential processes, then the cycle time is proportional to the sum of the transaction costs in these processes. Otherwise, when concurrent processes are involved, the total cycle time could be more a function of how these processes are connected, rather than a function of the sum of the individual transaction costs.

We recap the above discussion into a ***valuation theory for IS***: Transaction cost and cycle time can be applied to measure the quality and productivity for any personal, organizational, and the societal IS. The value of the Web as an IS, for instance, can be substantiated as the sum of the values of all contributions that the IS makes to the tasks by all people. One of these tasks is college applications. The difference between the total expenditures on college applications (e.g., the application fees, sales of all college data books, and personal inquiries and trips) before and after the Internet indicates a lower bound of the fungible value of the Web on this task. The values of the reductions in transaction cost and cycle time for all other tasks due to the Web can be assessed case by case in a similar way. Generally speaking, the so-called "red tape" is precisely transaction cost, and the amount at which one is willing to pay to facilitate/remove it is its valuation according to one's utility function. The tax breaks offered to attract a direct foreign investment is an example. The value of a proposed global database query system to an organization is, according to this theory, minimally calculable by compiling the time its employees spend on the phone and meetings that the new IS could save. The point is that the value is measurable, and the measures of reductions in transaction cost and cycle time are feasible. This valuation method is applicable to both a priori planning and post priori auditing.

The phrase "value creation" in the IS definition is generic, of course. It refers to any value proposition that the stakeholders of the IS determine to be suitable, such as enabling supply chain integration, renovating procurement processes, and enabling particular e-commerce applications. The valuation of such contributions may be self-evident, in and of the functions provided themselves. If so, then nothing more is needed. However, we submit that underlying all these particular value propositions are the generic value of reductions of transaction costs and cycle times for the missions. They promise to supplement the direct valuation; and more importantly, when direct valuation is difficult to come by, they provide the measures needed. Therefore, we present the following generic elaboration for the generic value creation phrase:

The Value Principle of Information Systems: *An IS creates and connects IS elements to reduce the transaction costs and cycle times of the enterprise that it supports, at the personal, organizational, and societal levels.*

A ***corollary*** is that the IS is itself designed to minimize its own internal transaction costs and cycle times. That is, the valuation applies to the design of the IS, as well.

Another ***corollary*** is the recognition of the following generic design principles needed for IS to minimize transaction costs and cycle times: digitization of IS elements, simplification or integration of transactions, and connections for concurrent access to resources and execution of tasks. These three design principles will be elaborated later in Chapter 3.

At this point, we review the notion of a "connected world" next.

1.3 The Connected World: human value networks using systems of information systems

The world is connected, as everyone says. So, we travel, work, and socialize in a world where most parts of it are not isolated from any other parts. Some even say that the world is "flat" as a global village. However, how to understand this connectivity? The world will not change regardless of how we see it, but our understanding of it will; and this change in understanding can lead to profound new results that affect our work and lives, and may even ultimately benefit the world. To enact on the connections of the world and seek new results, we need to go beyond semantic acclamations. Again, the particular perspective here is IS.

The most obvious evidence of a connected world is arguably cyberspace - the wired and wireless networking of persons, organizations, and habitats at the global scale. Adding on top of the physical space networked via human or machine interactions by land, sea, and air, this cyberspace presents a connected world. The connectionist definition of IS strives to go further. We ask, are products connections of parts? Are organizations connections of persons, enterprises of processes, and processes of activities? Are social networks connections of persons, and so are nations, families, and religions? Are economies connections of systems, and systems of systems, such as firms, factories, and, yes, information systems? In a unifying way, can we simply say that a society, or an economy, is made of ***human networks*** that operate on resources of value creation to discharge common missions? Here, networks and connections, and networking and connecting, were used interchangeably to highlight the notion of networking.

To highlight the notion of networking is to make way for this assertion: the emerging network science helps establish the much needed basic understanding of what is a connected world, in which IS belong. Network science came from disparate studies of biology (e.g., diseases and insect colonies), engineering (e.g., artificial habitats and systems), and sociology (e.g., social networking and group behaviors) that synthesized on certain common scientific methods and analytic findings. For many, the driving force of this new field is really the new phenomena of social networking using cyberspace. For instance, the traditional connections of humans in a society are well-known to sociology, but the cyberspace connections of humans are not - the latter not only is overwhelmingly versatile and numerous in quantity compared to the connections before the Internet, but they also promise to change the social norms and constraints. That is, “social networks” is not just an observation of facts (a noun), but susceptible to change and design (a verb). This ability to change, to design, to evolve rapidly makes the network-scientific study of social networking a must for, e.g., fighting terrorists, monitoring cyber-security, and promoting all sorts of ideas and commodities on the Internet.

We establish the essence of the network-scientific understanding of the connected world here, with more salient details elaborated in Chapter 2. Our connected world has yielded unlimited possibilities for human connections. Cyberspace has vastly opened up the relatively stable genres of traditional connections for new expansions: mass-customization design, or turning manufacturing into service (personalized products, agile processes, and extended enterprises); collaborations at work (company intranet) or professional promotion (open source communities on the Internet); and congregation (mobility among habitats and acquaintances networks). However, the greatest potential comes from serendipity: chance interactions among humans for any value propositions and collaborative value creation at personal, organizational, or societal levels. For the ideal IS, it supports this connected world every step along the way, and draws from the connected world the IS elements that it comprises. It even immerses its connection in the connection of cyberspace. An IS should facilitate serendipity via the IS elements within the scope commissioned. The connectionist definition of IS actually envisions an IS to be a part of many systems of information systems pertaining to this connected world.

We further elaborate on this basic view here. To be precise, we define a connected world to predicate on cyberspace and other physical means of making interactions among humans, with the driving forces for designing and making connections being value propositions, or value creation. For simplicity, we also refer to this view of the connected world the ***human value networks***. The connected world is an all-encompassing human value network of human value networks each of which may be facilitated by IS in the pursuit of their particular values. As discussed above, this view guides the design of IS (see Chapter 3), and hence has direct implications on how we behave in the connected world and reap benefits for all.

EXERCISES

1. What is openness and scalability of an IS following the connectionist definition?
2. How does openness and scalability define systems of information systems?
3. What should be some of the design principles for IS in the connected world?
4. What are the Pareto distribution and the so-called 80-20 law of operations management (e.g., inventory control, bill-of-materials, and office tasks)?
5. What is the decay power law? How does it describe the Pareto distribution?
6. What do you expect to see if you plot the size of cities (the Y-axis) against the number of such sized cities (the X-axis)? Would the pattern change in the following cases if you substitute other appropriate measures of size for the population measure in this case: the distribution of incomes for persons; number of times individual articles being cited by others; memberships at social networking sites (or destination e-commerce sites)…
7. What is six degrees of separation? What is the small world proposition?
8. How do social connections between congregations (e.g., habitats and nations) differ from those within them? What are "long connections" and outlier connections?

The first three questions are rather self-evident: Both openness and scalability are applicable to any connections of an IS. They prescribe how the IS elements within an IS should be connected in order to make the IS connectible with others, and they also prescribe how systems of IS could be "clustered" from connecting individual IS. For example, a system of five information systems may be developed from connecting just the persons, just the information resources, or just the infrastructure; but they could also connecting all five IS elements across the systems horizontally and then vertically. For the resulting system of systems to be open and scalable, these connections must be, too; and the more open and scalable the connections of the individual systems are, the easier their connection into a whole system will be.

That is, the openness and scalability of connections incidentally represent some of the basic requirements for the design and construction of IS elements if they need to be connected flexibly across information systems. Clearly, an IS does not have to be open and scalable, and many existing systems are completely proprietary or even "hard-wired". However, when one seeks to promote value propositions with the help of IS in a connected world, then making both the IS and the IS elements open and scalable becomes advantageous. It follows that an IS of IS must feature open and scalable connections within and across. Therefore, as a design principle, an IS with this vision should employ and deploy open source technology for making the IS elements and their connections, to the maximum extent possible.

The rest of the questions explore the intellectual nature of the connected world. The approach embraced here is to focus on human value networking: How humans network themselves; how humans connect "things"; and how these connection laws may guide IS design? We start with empirical evidence exhibited in previous practices.

The Pareto distribution and 80-20 law are common in virtually all operations. The classic example is inventory control: a few items account for the lion's share of value while a large quantity of items amount to small percentage of the value. Therefore, the control should focus on these few high-valued items, such as gold nuggets, and leave the "majority", say bolts and nuts, alone. The distributions of office tasks as measured by labor required or value added and bill-of-materials pertaining to complex products show similar patterns, too. Thus, it has been a common practice of management in any time and space for the manager to concentrate on the 20% of tasks that account for 80% of the value.

These patterns are generalized into the so-called decay power law of probability, or the negative exponential distribution, see Section 2.1 of Chapter 2. Taking the distribution of city sizes as an example, very few cities have mega populations while a lot of cities have a very small population. When the data are normalized into percentages and smoothly plotted on a (X,Y) plain, they will show a curve where the left end shows the maximum size as marked on the Y-axis corresponding to a very small percentage on the X-axis. At the other end of the curve one sees the maximum percentage on the X-axis corresponding to a very small size on Y (see Figure 2.1). The same class of decay power law holds for income distribution, citations, and popularity of e-commerce sites. A common property to all these cases is a propensity to ***preference by choice*** when humans congregate. Of course, as in the case of habitat and income, one could debate that to what extent such preferences are bounded by factors that one cannot control, or subject to design and modification. At the least, IS design could benefit from understanding these connection laws as some generic built-in usage patterns to guide the connections of IS elements.

Opposite to choices, ***natural binding*** by blood, resources, and other mechanisms or constraints of making a living also drive human networking. Thus, many congregations are arguably formed naturally or inherited, rather than by free will. Managerial and mandated organizations are one example, and tribes and religious sects are another. One could argue that even choices that are based on fixed attributes represent actually some bindings, as well. Examples include professional associations, interest groups, and even self-regulated open communities on the Internet. A country, in the largest sense, is a habitat of natural binding, too. The reason that one wants to distinguish binding from choice is to recognize another basic class of human networks: the small world, and reap its promises for IS design, too. No scientific rule says that the small world phenomena occur only to human congregations formed by natural binding; but we suspect that this is the case. At the least, we feel very comfortable to expect human networks that follow this class of connection laws (binding) to exhibit the small world properties. The commonly accepted definition of small world phenomena is a congregation that shows the so-called six-degree separation.

A degree of separation is an intermediary required to connect two persons. The children and parents are of zero degree separation because they know each other directly, without having to rely on any others to make the connection for them. Friends are of zero degree separation between them, too. However, the friend's friends will be one degree separation from the person in question. The friend's friends' friends are of two degree separation, and so on. Therefore, a small world congregation, be it physical or logical, is one where no member is separated from any other members by more than six degrees. It was hypothesized that the United States is a small world. Some suggested that the whole world is one. The burden of proof may be unbearable in large cases. However, we can discuss some provable implications.

An interesting observation of bounded congregations, or small world human networks, is their recursive structures. That is, a small world may consist of a few densely clustered subnets linked by only a few connections between them – or long connections between clusters. Needless to say, these clusters may show similar structures when one looks closely at their internal distributions of connections. By the same token, small worlds may cluster into super-small worlds by long connections with one another. This observation conforms to our common sense about human habitats. For instance, a country is densely connected from the within, but only sparsely connected from some few nodes with some other few nodes in another country. Thus, one could even consider this topology, i.e., densely connected lumps with long connections between them, to be a signature or working definition of a small world congregation. It is worthwhile to stress that long connections are outliers and exceptions, and they make the small worlds connect. Christopher Columbus, for example, was an outlier who provided the long connection to the New World. The beauty is that outliers and exceptions can be cultivated, designed, and managed, out of natural binding. International exchange programs (students, scholars, leaders, etc.) between countries are a ready illustration for creating long connections.

We submit that these long connections may hold some of the most valuable principles for IS design, since they are unobvious to the point of being counter intuitive. In short: outliers count, and facilitating exceptions may provide the most cost-effective applications of IS. If the decay power law teaches one to concentrate the IS software functions on connecting the most valuable IS elements within and across the organization, then the long connections reveal the necessity to explore the promises of certain classes of usage at the tail for linking up lumps of applications. Data exchanges and 'tunnels" of repositories come in as some ready examples.

There are many other (possible) types of connection laws, each of which may define some particular genre of networks. The most fundamental and prototypical one is the so-called random graph, where a node connects to other nodes by an equal chance. Many networks may be driven by desires that researchers call them collectively as centrality (to facilitate the average distance between nodes in the network). At the other extreme from random graphs are totally regulated networks such as the inter-state highway system and other artificial physical connections. They may manifest themselves in mission-specific connection laws for IS.

In general, network science uses mathematical models, especially the graph theory, to capture the analytic properties of any human networks and complement the traditional knowledge of social and economic sciences. Many of the peering results were published in Nature, Science, and other leading journals of natural sciences, in particular applied physics.

While leaving these results for Chapter 2 to review, the above discussion highlighted their essentials. The basic point is that the human networking models are scalable to represent any human congregations from persons, organizations, and societies; and hence uniquely suited to provide the context of connections for IS. More specifically, if an IS is a part of many systems of information systems in the connected world, then all the persons of this IS join with the other people of such systems of IS and constitute a "consortium" of human value networks. They could potentially tap into all IS elements of these systems of IS to enable the value creations sought. Both the individual IS and the IS for the whole of them are bound to exhibit certain connection laws in these value networks, stemming from the basic properties revealed by network science. The IS, furthermore, is also a tool for the management of such connection laws and the design of new ones to optimize the value creation for all stakeholders.

At this point, the notion of Web-centered and person-centered IS in the IS definition of Section 1.1 should become self-evident. The term Web-centered delineates the Web as both a tool for making connections and the scope for possibly connecting the IS with other IS as systems of IS. People are the ultimate users and stakeholders of the IS, hence their networking for value creation ultimately drives the design of IS. The term person-centered reminds the designers that the IS must be flexible for the individuals to use, and be strategic for the persons to collaborate - developing and pursuing value propositions.

The Networking Principle of Information Systems: *An IS maximizes its value by being an enabler to the global human value networks. It networks with other IS as its users (the persons) do, and uses networked IS elements to facilitate value creations from the networking.*

The first ***corollary*** of this principle is to design openness and scalability into the connections of IS elements, and maybe into the construction of the IS elements themselves.

The second ***corollary*** is the recognition of these generic connection laws for networking: preference in usage (focusing on the distribution of value added), long connections by usage (focusing on the tunneling effects of exchange in IS elements), and other generic and mission-specific connection laws such as centrality (focusing on spreading out the density of connections in the network, or the average distance between nodes).

The third ***corollary*** is concerned with the implementation of the above generic IS design principles: maximize the benefits of open source technology and societal cyber-structure and pursue as possible Web-centered and person-centered connections of IS elements.

The connectionist definition of IS is now fully explained. The next section applies this definition to trace the evolution of the field of IS since its origination in 1980's.

1.4 The Evolution of Information Systems

Does the connectionist definition of IS explain the evolution of IS practices in the professional field since its scholarly conception? Do we see empirical evidence of such notions as systems of information systems? We continue the above discussion and put IS to action: How this connection technology enabled the recent innovations of business design in, particularly, manufacturing; and how it evolved along with the innovations.

The history of information systems is arguably as old as human civilization itself; or at the least, as old as when the first written language appeared on earth. Question: Why did humans invent symbols? Answer: To record information. However, the academic articulation for information systems as a separate subject of scientific study and education emerged only around the 1970's (see, e.g., Gordon Davis and Margrethe Olson 1974). Practically speaking, the field of IS emerged as a solution to the limitations of the computer applications before it: number crunching. The basic argument was that information is much more than data processing, and a system that generates management information (e.g., sales, accounting, and inventory analysis) is much different from an electronic brain that does scientific calculation. Thus, the new field was branded Management Information System (MIS), with its contrast, the old days computing, labeled Electronic Data Processing (EDP). This concept blended computers with mainstream management, but it also prompted traditional organizational behavior scholars to refer to it as the computer-based IS, as a qualification of an organization being an information processor.

However, with the rapid explosion of information technology (IT) and the pervasive application of IT, the field soon realized that the power of IT (even just for business) did not restrict to management. The term MIS, rather than broadening the appeal of IT in general, actually relegated it to a special segment of promises. Thus, theorists and practitioners now customarily drop M and refer to the field simply as IS: Information Systems; i.e., the application of IT in all aspects of enterprises and extended enterprises, from management to production and logistics in all sectors of the economy and the society. The connectionist definition of IS follows this broad interpretation but further specifies its unique intellectual nature to assist design.

From the perspective of this connectionist definition, we may classify EDP a specific connection of the following IS elements: EDP professionals (e.g., computer technicians, data entry clerks, and method engineers and EDP managers), data crunching software, data resources, main frame computer, and remote terminals. In a similar way, MIS is a connection of managers, MIS professionals, managerial report generating software and data crunching software, main frame, mini, and personal computers, and local area networks. Some variations of MIS, including Decision Support Systems (DSS, see, e.g., Steve Alter 1980) and Expert Systems (ES, see, e.g., Nils Nilsson 1980) can be classified this way, too. There, DSS features analytics and group collaboration software to facilitate decision makers' jobs, while ES seeks to automate certain classes of professional tasks (including internal medicine) by embodying decision rules and knowledge representations. Both require versatile databases. Neither recognized the role of openness and scalability for their IS elements and connections, nor made them a requirement.

Then, sea changes came in 1980-1990 due to new enterprise IT, which enabled numerous new models of enterprise engineering in, especially, the manufacturing sector of economy. The routine management applications of IS were completely aligned with manufacturing functions, by such models as enterprise resources planning (ERP, e.g., the SAP system). As a result, extended enterprises became a norm for IS applications. The notion of open and scalable connections started to make sense as enterprises discovered the value of broadening the small set of regular suppliers to semi-regular supplier pools (e.g., certified suppliers) and network with them. A second wave came in the form of the Internet in 1990-2000. Globally scaled networking for customers and companies entered the realm of enterprising and business design. Since 2000, including this decade, the field is wide open for new innovative business designs to thrust in all directions as long as the progress of IS/IT can support them. The connectionist definition of IS uniquely sheds light on this evolution of IS design.

What happened since 1980 can be summarized in three topics: agile manufacturing, e-commerce, and social networking. How does the IS definition describe them?

EXERCISE

1. What are functional IS, such as sales, payrolls, and accounting in the administration sector of a company; and process planning, production scheduling, and shop floor control in factory? What make them “islands of automation”?
2. Why is a database system an open and scalable way to connect standalone application files and software, while structurally integrating them?
3. What are computer-aided design (CAD), computer-aided manufacturing (CAM), manufacturing execution system (MES), computer-integrated manufacturing (CIM), concurrent engineering (CE, or simultaneous engineering), agile manufacturing (AE), and mass customization?
4. What are the differences between ERP, product data management (PDM), and product life cycle management (PLCM)?
5. How does supply chain integration compare to supply chain management, on the one hand, and e-engineering on the other?
6. What characterizes e-business, on-demand business, and globally integrated enterprises?
7. Is there any concrete technical characterization of systems of information systems?

Of the three topics, agile manufacturing, e-commerce, and social networking, this book will discuss the last two in Chapter 2 with great details. Here, let the focus be agile manufacturing. More precisely, let the focus be the evolution of agile manufacturing and its repercussions on IS. For convenience of discussion, we recognize these six main divisions of a manufacturing enterprise: administration, product design and production planning, (execution of) production, supply chain, demand chain, and customer services. Each of these divisions consists of its own functional areas and operational processes, with the administration also including the enterprise level management and control. Collectively, they encompass the entire enterprise.

A functional IS dedicates itself to a particular function(s) in a particular division. The scope of the IS elements and connections define the dedication. These information systems are islands of automation simply because they are mutually exclusive with no online connections in between: any given IS element in any of these IS islands cannot inter-operate with any other in other island. Thus, a sales manager who wants to determine a "rock bottom" price for a product, for example, does not have access to the information about the sale product in the accounting IS, nor to the information in the production IS. This notion of islands of automation equally describes the separation of one enterprise in a supply chain from another, of course. The central concept is straightforward: if one needs integrated wholly view of certain IS elements across a scope, then one needs proper connections of such elements throughput the scope. They become islands of automation when the required connections do not exist.

A database, such as Oracle, DB2, and PostgreSQL, is an integration of data resources (see Chapter 5 for the whole concept and design of databases). It features a conceptual schema to provide semantic (logic) integration for the whole spectrum of its applications, and implements the integration into storage structures using generic access methods (the internal schema). It derives (groups of) external views from the conceptual schema, each of which is fine-tuned for the data input and output designs of some particular applications (or application families) that it supports. The provisions of a full-fledged database system typically include tools to run assortment of programming languages, as well as some generic native programming facilities (e.g., ANSI SQL). The internal schema allows a database to be transported from one hardware platform to another and minimizes the transaction costs for doing so. The external views and programming facilities together supports foreign application software developed elsewhere outside the database environment to run on the data resources integrated in the database, without much need to modify the software – or, again, with minimum transaction costs.

When the external applications are some functional IS in and of their own right, or, if one connects certain functional information systems by virtue of connecting their information resources, then the database technology offers a relatively open and scalable way to construct the connections and the resulting integrated information resources. The openness is achieved because the design methods for developing all three schemas are generic, and hence applicable, to a great many classes of information resources in a great many information systems. The scalability comes from the extensiveness and changeability of the database technology itself, delivered through, e.g., the relational system and SQL programming environment. With this integration, the original application programs can continue to run for their original IS users and all others when needed, with minimal transaction costs. Thus, connecting functional IS via an integrated database is a ready example of open and scalable construction of IS elements and connections. The three schema model of databases is itself scalable to the integration and inter-operation of databases within and across enterprises, on the Web or not (see Chapter 5).

The third question is concerned with the connection of the product design and production planning division with the production division. A CAD system is an IS that connects design engineers to drawing and engineering analysis software and thereby enable them to produce digital product data and designs for the ensuing product development tasks (e.g., process planning). The system often uses proprietary computing hardware and networking infrastructure. A CAM, on the other hand, connects machinery (and operators) to the dedicated machining controls software, hardware, and infrastructure. Cluster such CAMs and enrich them by connecting to automated shop floor control data acquisition and feeding, and an MES results. Extending the MES to include connections (or integration) to production scheduling IS, inventory control IS, and all other functional ISs of the production division will provide the minimum CIM. Connecting it with CADs, process planning IS, and select functional ISs in the administration sector progressively will expand the CIM towards covering the entire manufacturing enterprise. Connecting CADs across the product design and production planning division and overlapping the design process with the manufacturing process (e.g., team up design engineers with manufacturing engineers) will give rise to CE. Technically speaking, there have been many different designs of the above models, each of which typically come from some particular way of making the connections in the particular models.

Agile manufacturing is as much a business design as a technology. Unlike the other models discussed above, AE expressly calls for the involvement of customers in the model as a driver for the chained reactions through all six divisions. In a sense, we can consider AE an implementation for the ideal of mass customization: Make the manufacturing system agile as to be able to respond to customers' on demand orders. Clearly, this is a high end vision that requires a high end IS to support it. We stop our discussion here by simply stating that the ideal IS for AE must be a system of systems, whose design is still unfolding today.

An ERP is usually a tight integration of select IS islands in administration, production, and those for inter-operation with the supply chain. Vendors often provide total solutions for the integration as a standalone ERP IS running on its proprietarily designed IS elements. The model of PDM tends to be implemented by inter-operating the information resources that contain product data from IS in any divisions required. For instance, the product data captured in customer services IS (failures on parts, functions, etc.) will be connected to the product data of CIM, by virtue of some unifying data models. The individual systems so connected in this case will continue to operate autonomously.

The model of PLCM is even looser, connected often by the enterprise's internal cyber-infrastructure and some common user interface to switch in between the member systems of the PLCM confederation. In this sense, one may say that the PLCM is embedded in the enterprise cyber-infrastructure, whose appearance is the collected presentation of all component ISs. This loose connection is more a result of practicality than by any logical design. Conceptually speaking, the PLCM encompasses the entire manufacturing enterprise since the life cycle of a product starts with customer demand (marketing) and business strategizing, and moves through all other sectors. To tightly connect all the IS elements involved across software technology and vendors would present a major challenge to the field. The practices of PLCM IS in the field clearly illustrate the notion of systems of IS.

Supply chain management is comparable to PLCM, except that the scope now is the entire extended enterprise of the chain. It remains mainly a managerial practice depending directly on IS support. However, under this loose umbrella, the notion of supply chain integration tends to imply some technical integration of supply chain tasks beyond savvy management by humans. A famous example is the CFAR project (King 1996): the connection of Wal-Mart's procurement IS with Warner-Lambert's order processing IS and ERP, by dedicated application software (processes) over the Internet (infrastructure). Albeit dated, this practice still represents a top-notch vision and a high bar in the attempt to tightly integrate retailer IS with supplier IS across the supply chain. This integration has reportedly reduced at least the cycle time of inventory (e.g., Listerine) replenishment for Wal-Mart. The connectionist definition of IS views the supply chain IS a system of systems. Indeed, when the supply chain is considered an extended enterprise in and of itself, then all the enterprise IS models discussed above may be applied to this extended enterprise, as well. The e-engineering model is precisely the application of the CE model to the extended enterprise of supply chain as a whole. The e-engineering IS will be an IS of the prime's IS and the suppliers' IS where the product design information resources and design engineers are connected in some way.

Answering the sixth question requires a new concept: the demand chain, or the customers and the customers' customers, and so forth. Demand chain and supply chain could be mirror images, of course, except that customers are commonly people while suppliers are companies. All three models, e-business, on-demand business, and globally integrated enterprises, are based on demand chains and feature the (direct) collaboration among people either as the customer or as the knowledge worker for common value creation. Clearly, in all the above models, the easiness of making the connections depends squarely on the openness and scalability of all the IS and the IS elements concerned. The fundamental values of these innovations in business design are reduction of transaction costs and cycle times in the execution of all functions throughout the value chains, such as the time to market for new products.

The seventh question highlights a fundamental aspect of IS: the connections could be tightly controlled both proprietarily and technically, or just be some loose forms of voluntary collaboration. The former typically requires an integrated database or computationally synchronized distributed databases for the whole IS, and hence makes it a singular IS. The latter, in contrast, would be considered some system of IS. The key point here is that the connectionist definition of IS consistently explains the evolution of IS as an innovator for business designs, manufacturing or otherwise. The concept of human value network uniquely describes this trend.

We will discuss innovations in business designs in general, as IS value creation, in Chapter 2, which broadens manufacturing demand chains to all aspects of human value networks, especially service (e-commerce) and social networking. The following statement draws from the concurrent and converging evolution of IS in all sectors of economics:

The Unification Principle of Information Systems: *An IS is a unifying tool for economic enterprises. All IS elements, excepting application programs, are generic in nature and may be useful to any other IS elements for any IS in any functional areas and economic sectors. Thus, the design of IS should seek the unifying effects by connecting IS elements into systems of IS.*

The history of IS as revealed by the connectionist definition shows something rather impressive: the strong perseverance of IS. That is, IS tend to evolve rather than do or die; they weather the changes in the volatile IT industry and funnel such revolutions into robust business design innovations. The next section discusses how the continuity may shape the design of IS.

1.5 The Journey of Information Systems: design for life cycle vs. design for sustainability

Manufactured products, from personal daily effects to big machinery and buildings, all have definitive life cycles just as biological entities do. Even organizations have legally mandated starts and ends. Therefore, it is fitting that their design and management are often marked with tasks that correspond to the generic stages on their life cycle: product planning, engineering design, manufacturing (fabrication, construction, etc.), sales (implementation, etc.), services (operation/control, maintenance, etc.), and termination (disposal, etc.). Only recently with the rise of the sustainability concerns has the field started to consider the eternal effects of products and promote recycle and reuse. New methods such as design for sustainability and rebirth analysis (Jeff Morris 2011) seek to extend the horizon of product life cycle and design. In a way, the notion of sustainability extends the planning horizon into eternity.

As revealed in Section 1.4, in the spirit of Douglas MacArthur's famous quote, "old soldiers never die, they just fade away", one may say that ***IS never die but just reincarnate***. Some IS elements (e.g., information resources) may survive the organizations which initiated them and owned them, by being incorporated into other IS (e.g., taxation, Google Web homepages, and archives) as some elements or member systems. For an IS in a continuing enterprise, many of the IS elements, especially the software and hardware, may get replaced or subsumed into other elements many times over, but the real gut of the IS, as defined by its mission (particular value creation), contents (logic and information resources), and connections (persons and supporting resources) tends to perpetuate. It is arguable that the life span of IS is at least as long as its host company. A more liberal view may even compare the life of IS to that of a human being which perpetuates into offspring forever. This view in fact regards IS to have an eternal life cycle, which should be recognized as such, rather than some terminal life span.

This brings this book to ***sustainability design for IS***. What is it, however? An intuitive view could focus on the recycle, reclamation, and reuse of IS elements, and strive to incorporate these goals into the design of IS. We have no quarrels with this view. It is good and necessary for a connected world. However, we would rather focus on the design of connections to substantiate the uniqueness of IS sustainability: make IS elements (maximally permissibly) open and scalable for connections, and make the connections of IS elements (maximally permissibly) open and scalable. This is our definition of sustainability design for IS.

This sustainability brings about another dimension of IS innovation. The subtitle of this book, ***the connection of people and resources for innovation***, now has three levels of connotation to link IS and innovation: an IS connects for human value networking; an IS connects to become enabling elements; and an IS connects sustainably. They lead to a new perspective to IS design. In comparison, while the traditional IS design methodology categorizes the design tasks in accordance with a terminal view of the IS life span: planning, analysis, design, construction, implementation, and operation, the new design perspective recognizes, accommodates, and promotes an eternal life cycle for IS in a connected world. The innovation comes from the new values enabled by the new connections of people; the new connections of resources; and the new connections of people and resources.

EXERCISES

1. What common IS techniques support the sustainability of an IS? (Hint: think your PC: what administration apps/functions your PC has that support its sustainability?)
2. Does the life cycle view still apply to IS that reincarnate? What may categorize the new view away from the old?
3. How can we expand the reincarnation view into an IS design methodology?
4. How do the following concepts of IS planning differ from each other: an IS roadmap, an enterprise IS plan, a phased IS plan, and a specific IS plan?
5. Why does design for connection require more professional expertise than the traditional life cycle design does? Should the expertise reside in-house? Can it become a core competence for the enterprise?
6. What generic IS design methods have proven to be of long lasting value? (Hint: think what basic kinds of “things” or terminologies have stayed forever with computer?)

The concept of IS sustainability is actually closer to our survival than many may have thought. Just think what if we lost all the digital data on our PC; all the digital data on our company’s PC; all the digital data on all companies’ computers; all the digital data on all the government computers; and all the digital data in the world. Or, for that matter, just think what if we can no long read all the digital data that we have saved. Is there any possibility imaginable at all that Microsoft might all of a sudden be “ruined” and their support to all MS products abruptly stopped (or severely disrupted), and thereby compromised the continuing functioning of Windows and Office on our PCs? To be a little more realistic, would it still ruin us if the sudden ruining of Microsoft took place over a period of, say, a month or a year, during a crisis where other vendors were also be hard pressed to take over the business completely? In fact, a dark age would not be unthinkable in the worst, oh no, near worst case, of disastrous scenarios on IS.

Luckily, of course, the darkest scenarios seem sufficiently remote to warrant any loss of sleep at night. However, lesser disasters in IT disruptions do occur, such as those due to terrorist attacks and earthquakes. The IT industry has proven its sustainability during these unfortunate and unwanted tests, by having designed and built some basic sustainability into their systems. They include parallel and redundant systems (resources and applications), backup and roll-back support to systems, and collaboration among (distributed) systems. Needless to say, the sustainability design relied on sustainable connections to work, especially when collaboration among systems is required. The same principles of sustainability (especially recoverability) are commonplace virtually in any PC design, not just for complex computing or IS.

Therefore, the industry has been aware of the defensive side of sustainability design for IS, including saving energy and materials throughout the life cycle of IS hardware manufacturing and operation to cut the cost to customers and society. However, its progressive side still awaits recognition. We argue that when sustainability is linked up with the reincarnation of IS, either in the standalone sense or as a member of systems of IS, design for connection has a powerful positive side: It should promote the eternal effects of IS on facilitating value creation for the connected world by incorporating the evolution, or the permissible future networking of IS, into its design roadmap. The key is the strategic planning for the roadmap and the core competence to (adaptively) enact on the roadmap into the future.

That is, an eternal life cycle is still a life cycle except that the planning phase must be a part of the enterprise's long term strategy, and the operation phase oriented to allowing for constant renovation. Therefore, we recognize this new life cycle of IS: ***strategic planning*** (business designs using IS); ***specific planning*** (accountability for value creation); ***analysis*** (for IS elements and connections); ***design*** (of IS elements and connections); system ***construction***; ***implementation***; and ***renovation***, which may lead to revamping, expanding, or merging of IS elements and connections. In a way, the last phase, renovation, may be considered as a recursive or iterative cycle of the previous five phases, driven by new designs of value creation. Compared to the traditional life cycle, the main difference is the scope of IS strategy (equal to the business vision of the enterprise), the extent of IS horizon (societal), and the replacement of operation with renovation as the last stage.

The IS field has accumulated many methods for planning IS from some given mission, which may be mandated by the (top) management without the IS professionals' involvement. Industrial IS planning methods tend to be based on common sense, rather than scientific justification; and vendors have codified many tasks and procedures involved to make their application easier. In essence, these planning methods are some template whose application requires experienced IS professionals to calibrate it on the particular cases at hand. Such software is well suited for on-job training. Strategic planning for IS, on the other hand, requires competence in the development of business strategies for the enterprise. Since business strategy is in and of itself a major subject of study, we content ourselves to investigate the unique and particular perspectives of IS, i.e., how does IS enable a ***business design*** for the enterprise, and possibly enable its innovation (e.g., new business models; products and services; business spaces; and strategic practices) by facilitating new human value networks. This is the subject of

Chapter 2. In this context, the second phase of information system planning, developed in Chapter 3, is the design of the overall IS structure (e.g., the scope of IS elements and the strategy of connection) to implement the overall IS mission in a current IS at the appointed time.

The second phase of IS strategic planning is the planning of an IS roadmap for the enterprise, too. The roadmap may be staged, and be recursively enhanced on specificity, depending on the time frame and the level and scope of development. Its purpose is to knit together long and short term IS plans (for particular missions) to yield an overall enterprise IS vision. These plans will feature progressively more specific and narrower definitions of IS elements and connections as the vision moves from long term to short, and from high end aspiration to immediate budget constraints. The point here is that, IS visions should not be buried in IS reality check. Even an unrealistically ambitious IS roadmap can be accompanied by a realistic time frame for eventual implementation so long as the visions sought are attainable and justifiable. Only the specific IS plan for the current IS is targeted for immediate enactment, and hence only it requires the specification of all goals that substantiate the mission, and of all types of IS elements and connections that constitute the IS, to the point that ball-park budgeting becomes possible.

Another fundamental difference between the eternal life cycle and terminal life cycle views of IS is their last phase: renovation vs. operation. The operation of IS may be outsourced to some application providers or service bureaus, although significant organizations tend to run their IS in house even if they bought the IS from outside vendors. The reason for in house operation is the same as that for in house development: the strategic value of IS. If the value is perceived so high as being a part of the enterprise's core competence or even a strategic competitive weapon, then for control and protection the enterprise would develop the IS in house, or at least operate it in house. However, how low the value must go before a company outsources its IS has to be a measure that belongs to individual companies' discretion. Renovation clearly raises the threshold higher, whatever it may be. If a company values the IS so much as to align its business visions with the IS and commissions constant renovation on the IS – or, conversely, if a company finds it necessary to constantly renovate its IS, then the competency on IS clearly belongs in the company's core competency. At this point, it ought to be self-evident that the connectionist definition of IS recognizes IS right at the heart of any enterprises that connect within or across.

The last question of the exercises also indicates the scope of this book: it focuses on such methods for IS design that promise long lasting value, and leaves the more tenuous ones to on-job training using perhaps the generic skills acquired from one's education. For reasons of specialization, this book also leaves out hardware, operating systems and application programs, human-computer interface (e.g., GUI, Homepage, and natural language), and programming languages and algorithms to other textbooks in the computing discipline. This book will develop the competencies for processes analysis and database design in Chapters 4 -7. As such, this book develops the core competences of IS design in strategic planning, system (processes) analysis, and database design. Together, these results constitute a basic IS design science.

The Design for Sustainability Principle of Information Systems: *IS should seek sustainability and innovation in its design, to support an (eternal) life cycle of strategic planning; specific planning; analysis; design; construction; and renovation, for its envisioned value propositions, IS elements, and connections. Innovation comes from value propositions and connections.*

The science and practice of information systems have now been explained.

The rest of the book develops particular theory, methods, and techniques based on the concepts reviewed here. The next chapter analyzes the analytic properties of human value networks and thereby presents a set of generic principles and guideline for IS strategic planning. This foundation sets the IS design process in motion in the ensuing chapters.