Research Commentary: Toward the 24-Hour Knowledge Factory – A Prognosis of Practice and a Call for Concerted Research

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Abstract

The term "24-Hour Knowledge Factory" connotes a geographically dispersed team of workers in which members of the team are able to work on specific endeavors on a round-the-clock basis. A professional could work in the US on a standard 9 am to 5 pm basis. At the end of his or her workday, the activity is transferred to a colleague in China who works during daytime in that country. At the end of the latter's workday, the work is transferred to a third colleague in Poland or Romania, who in turn will pass the baton 8 hours later to the first worker in the US. Each member of the team works during the normal workday hours that pertain to his or her time zone. The use of sequential workers that underpins the concept of 24-Hour Knowledge Factory has some similarity to the shift-style workforce that evolved in the manufacturing sector as an adjunct to the industrial revolution. Just as the latter concept had a profound impact on the entire manufacturing sector, we argue that the concept of 24-Hour Knowledge Factory will have a major impact on the entire field of information systems, and that more research is needed in this area. The concept of 24-Hour Knowledge Factory is relevant for semi-structured work in both the IS arena as well as in other professional arenas such as finance, product development, marketing, and medicine. The proposed areas of research can help to create the IS infrastructure for supporting applications in these diverse arenas.

(Keywords: Globally-dispersed Teams; Accelerated Systems Development; IT Productivity; Strategic Reorientation)

Part I: Introduction of Concept

The term "24-Hour Knowledge Factory" connotes a globally distributed work environment in which members of the global team work on a project around the clock; each member of the team works the normal workday hours that pertain to his or her time zone. At the end of such a workday, a fellow team member located in a different time zone continues the same task. This

concept flows from the fundamental belief that, in most cases, a person can work most effectively during the normal daytime work period (roughly from 9 am to 5 pm). While one can temporarily work during the night, such a mode of operation is not convenient or optimal over an extended period of time. Further, by having three sets of individuals perform work over a 24-hour period, the objective is to drastically reduce the time needed to develop information systems and to facilitate effective knowledge-based processes to occur.

Evolution from Factory to Knowledge Factory: The notion of the 24-hour Knowledge Factory can be traced back to the industrial revolution. Since the installed equipment was scarce and costly, different sets of employees were scheduled to work in successive shifts so that the manufacturing facilities could be used on a round-the-clock basis. The use of the 8-hour shift system evolved over time. This involved decomposition of the manual tasks involved in fabricating an agricultural implement or a handgun into a series of tasks that could be performed relatively independently of each other with the assistance of different machines. Initially, each worker was directed to work 12-16 hours a day so that each machine could be used for an extended period of time. Then, the notion of having two shifts evolved. Based on new legislation on both sides of the Atlantic, the work hours were gradually reduced. The introduction of the shift system yielded benefits in terms of higher productivity of each machine, reduced production times, and lower prices to customers. However, it also created social and health issues by requiring the person to be work in an urban setting, usually away from other members of the family, and that too at odd hours and changing work schedules determined by the idiosyncrasies of the manager in-charge of assigning workers to different shifts.

With the advent of electronic computers and the diminishing costs for telecommunications, one developed the notion of 24-hour Call Centers. Depending on the time of the call, it is automatically directed to a call center that is active at that time. Using a cluster of three to four call centers located in time zones 6-8 hours apart from the time zone of the neighboring call center, one can ensure that all employees of these geographically distributed call centers are working during the daytime in their respective countries. The notion of multiple support centers was subsequently adapted for supporting global communications networks over time. Now it has become feasible for one to use a geographically distributed workforce of highly trained

professionals to complete an endeavor in a much shorter timeframe as compared to a scenario in which all personnel are based at one location, irrespective of where location is.

Whereas a manufactured item was the end-product in the case of the "24-hour factory" that emerged as a consequence of the "industrial revolution", knowledge-based services and knowledge-based products are the end-deliverables in the case of the current "information revolution"; hence the term "24-Hour *Knowledge* Factory". The use of the term "factory" emphasizes:
(i) the use of multiple sets of workers;
(ii) the availability of a set of base technologies to operate on the knowledge and to transfer the knowledge from one worker to another;
(iii) the shift-type nature of operations; and
(iv) the underlying idea of decomposing a big task into a series of components that can be tackled on a sequential basis.

24-Hour Knowledge Factory versus Globally Distributed Teams: The term "globally distributed teams" implies teams of people, in different parts of the world, working on the same problem. In most cases, but certainly not all, the teams may be working on different parts of the same problem, such as one working on the user interface and another working on the data analysis part. The 24-Hour Knowledge Factory is a special case of a globally distributed team in which the different teams work on a sequential basis that has been clearly defined in advance. For example, by involving three teams of specialized microchip design engineers located at carefully selected places around the world, a semiconductor chip design firm may create a virtual "24-hour knowledge factory" that utilizes the best talent in three continents, as well as an efficient design process that offers a faster turnaround time than conventional design approaches.

One could argue that the faster turnaround time could be attained by having three teams working in a sequence at the same location. This single location scenario would require one team to work at odd hours of the night; some persons call the latter type of shift as the "graveyard shift". Further, not all the high-talent designers are willing to move from their respective countries to a single location. The creation of globally distributed teams that transcend geographic boundaries

offers the potential to change the face of many industries. The 24-Hour Knowledge Factory concept places emphasis on leveraging the temporal boundaries for a company's benefit.

In the eighties, when one of us discussed the notion with representatives of leading banks in the US and Switzerland in the context of information systems, these representatives were taken aback by the idea. At that time, people around the world deemed the time difference between fellow workers to be a major negative - they thought the time difference would hinder their ability to perform the work and add significant overheads, time delays, and costs. Now, the perception has switched around - for many projects, the time difference is viewed as a strategic plus; it is this time difference that enables the creation of the virtual 24-hour Knowledge Factories. In software development, Treinen and Miller-Frost have studied global teams and noted that time zones are more significant than physical separation, and these time differences can be a competitive differentiator for firms who take advantage of them [Treinen 2006].

Figure 1 depicts a distributed factory with software design operations in three countries around the world. In this scenario, the three sets of workers are engaged in somewhat different tasks. A more authentic example of the 24-Hour Knowledge Factory would involve the workers working as true peers on the same sets of tasks.

[INSERT FIGURE 1 ABOUT HERE]

Structure of Work and Decomposition into Components: Prior to the industrial revolution, a person would be engaged in developing an item from start to finish. If a hammer had to be fabricated, the person would hold responsibility for cutting the wood, trimming the wood, polishing it; the concerned person would also be responsible for heating the metal and bending it to the right shape. In every sense of the word, the end product was a piece of art, manifesting the values of the artisan who created it from scratch.

The advent of machines changed the entire operation. Multiple persons, in fact sets of persons spread over two or three shifts, would perform micro-tasks on each item. The items themselves got standardized over time, thereby losing the customization aspect. The finished product was

one taken off the assembly line, resembling almost entirely the item that preceded it on the production line, as well as the item that followed it.

The concept of shifts was suitable for certain types of tasks, and inappropriate for other types of tasks. The fabrication of generic items like agricultural implements and military goods was facilitated by the availability and use of machines on an around the clock basis. But the shift concept was inimical to creation of many types of fine arts. If an artist worked for 8 hours, then an associate worked on the painting for another 8 hours, and a second associate worked on it for a third shift of 8 hours, then the master painter may deem the painting to be totally ruined and beyond redemption. (Note that there are instances where the multiple worker approach did work in the context of paintings of international repute. Paul Gauguin, the French painter, employed hordes of assistants in Tahiti to paint the background of several of his legendary paintings.)

Based on the above analogy, the 24-Hour Knowledge Factory paradigm is appropriate for situations where the professional endeavor can be broken down into components, different individuals can potentially work on such components with minimal support from their peers, and the work-in-progress can be transferred at minimal cost from one collaborating center to another.

Can the same 24-Hour Knowledge Factory paradigm be applied to manufacturing scenarios? Unfortunately, we cannot transport partially finished manufactured goods in split seconds from one place to another. But we can transmit the information related to manufacturing applications, such as that pertaining to design, engineering, quality assurance, and sales of individual parts, sub-assemblies, and finished products. Such information allows geographically distributed team members to contribute to the operations of a manufacturing plant even when not located in the same country! The same applies to information needed by accountants, architects, business managers, computer programmers, financial analysts, medical practitioners, product designers, and many other professionals. The paradigm is appropriate in all situations where the underlying knowledge can be digitized; further, it is most relevant for semi-structured professional work.

[INSERT FIGURE 2 ABOUT HERE]

24-Hour Knowledge Factory versus Call Centers and Business Process Outsourcing (BPO): A significant number of companies now operate call centers in different countries in a sequential mode. So if one calls the reservation number for British Airways, the call center that one is connected to depends heavily on the time of the call. If one makes a repeat call, the caller will most likely be connected to a different call center. If the call centers are operating as envisaged, the caller will not need to repeat the information, actually basic data that the caller provided to the first call center. Hence, it is basic data or information that is transferred, not knowledge. WNS and AllSec Tech [Wharton 2003, [1,2]]are examples of companies that are attempting to innovate call center operations leveraging such principles of workflow.

Even though the work in call centers is "white-collar" in nature, it bears lot of similarity to blue collar work. In other words, the work is inherently very structured. At the other end, the work performed by President George W Bush and other heads of nations and states is frequently crisis-driven and is inherently ill-structured. As shown in Figure 2, the concept of 24-Hour Knowledge Factory is aimed at the intermediate territory of semi-structured work, but not fully structured work or ill-structured work.

With respect to Business Process Outsourcing (BPO), the 24-Hour Knowledge Factory model differs in three major respects. First, BPO activities are usually performed at one or two centers only, not at 3 or 4 centers that are selected at strategic distances from each other. Second, in BPO, there is no implicit requirement that the work will be transferred, on a shift basis, from one collaborating center to another. Third, in BPO, the primary emphasis is on conducting activities related to the current business; on the other hand, the 24-Hour Knowledge Factory concept highlights the need to "build' knowledge over time, thereby improving overall capabilities on an evolving basis. Fourth, the BPO environment suggests a primary and secondary location, whereas the 24-Hour Knowledge Factory treats every center as an equal partner.

Use of 24-Hour Knowledge Factory paradigm in IS and non-IS fields: From the viewpoint of the information systems community, the 24-Hour Knowledge Factory paradigm can be applied to two kinds of environment.

The first is an obvious one pertaining to the design, development, and implementation of information systems in a manner that leverages the new paradigm. The use of the 24-Hour Knowledge Factory paradigm can allow each of these tasks to be performed at a faster pace and at a lower cost. In today's parlance, the 24-hour Knowledge Factory will involve "partial offshoring" or "hybrid offshoring" as an integral part of the endeavor, with one team being deemed as onshore and the other two teams as offshore. This distinction between onshore and offshore is primarily relevant at the time of initiation of a project – over time, the 24-Hour Knowledge Factory model seeks to establish a seamless integration that enables each site to be an equal contributor. Examples of this can be seen in the multi-shore operations of firms such as Pipal Research Inc. [Wharton 2006]. Pipal provides professional services that can be executed from multiple labor regimes (countries). Depending on the extent of interaction needed between the client and Pipal's analysts, Pipal configures a support team that is often spread across multiple countries – such as US, Canada, India, and China. Alternatively, the nature of work may be such that a group of onshore employees of Pipal would interact with the client, structure the work that needs to be done, and allocate it to for sequential (or semi-parallel) processing to teams in multiple countries in different timezones. Today, offshoring is done mainly to reduce costs; over time, the growth in offshoring will be fueled more by its potential to achieve drastic reductions in turnaround times for major endeavors.

The second involves the application of the 24-Hour Knowledge Factory paradigm to a broad range of other wide collar activities ranging from medical services to logistics planning, and from financial analysis to product design. Consider the functioning of the firm, OficeTiger[1] Inc., based in the US, India, Sri Lanka, Switzerland and the Philippines [Wharton 2005]. One-third of their deadlines are shorter than three hours, and about half of their deadlines relate to work that needs to be completed within a day. This firm provides a variety of services for financial analyses, accounting, asset pricing research and also support services for investment and corporate banking firms. Often, its clients complete a part of the work and hand over the remaining parts to OfficeTiger's analysts to perform online, on a real-time basis. The company has developed a management information system – called T- Tracks – that provides for fine-grained tracking of the work in progress at the various offshore teams. This system also provides

[1] Recently acquired by a large US financial services firm.

summary statistics, as well as control information on quality of output and overall productivity. Envisaged to be more than a management information system, T-Tracks is a platform for collaboration that allows multiple teams located in several geographically dispersed locations to work on the same processes and to hand-over tasks in a graceful manner. In cases such as OfficeTiger, the challenge for the IS community is to design, develop, and deploy the IS infrastructure that can be utilized by these industries in order to perform their respective endeavors at lower costs and with shorter turnaround times. Ideally, one would like to use the same IS infrastructure to provide 24-Hour Knowledge Factory capabilities to diverse arenas; in reality, the IS infrastructure may need to be adapted to address the specific requirements of different endeavors.

Potential for Greater Flexibility and Specialization: The 24-Hour Knowledge Factory paradigm mitigates five major constraints of the conventional factory environment.

First, it overcomes the need to work at odd hours of the day. All individuals need to work during day time in their specific country. The firm Beredium International has experts working in different time zones in the European Union and in Mauritius, so as to provide full–time accounting support to its clients without requiring that employees work in time slots that are not natural to their diurnal rhythms.

Second, individuals can work from home too. Prior to the industrial revolution, individuals worked from their homes and provided goods to buyers in the neighborhood. The Industrial Revolution moved the workplace from the home to the factory; and over time, one could sell goods in a broader marketplace. The 24-Hour Knowledge Factory paradigm can provide the flexibility for the individual to work from home, from the beach, from the airplane, and still have his or her professional services benefit consumers on the other side of the globe. Accordingly, we are undoing one of the major constraints imposed upon society by the Industrial Revolution.

Third, the Industrial Revolution discarded the notion of specialized artisans in favor of assembly lines producing generic goods; the evolving Knowledge Factories can bring the artisan back to center stage, emphasizing customization over componentized, and individuality over group

behavior. The new set of services can be tailored to reflect the individual skills of the worker, and to use them to create customized products and services. For example, one can now use the Internet to order a custom bicycle be manufactured to individual specifications and be truly one-of-a-kind. Broadening this example, we can envision a new generation of service workers who will help to design, manufacture, and market customized products utilizing the most cost-effective options at each stage. As one begins to access and use less expensive labor in places around the world, one can create custom products and services at lower costs.

Fourth, the new paradigm provides much greater potential for individuals to progress in their respective fields of expertise. Workers can gradually move up the value-chain and provide a growing number of higher-value services.

Fifth, conventional factories employed workers from very similar backgrounds and national origins. In the 24-hour decentralized development process, professionals from different cultures are concurrently engaged on all tasks, and can provide their cultural input on a continuing basis into all tasks at all stages of the process. This paradigm works better than existing mechanisms for understanding requirements from different cultures, thereby producing end services and products that command greater appeal in the global economy.

Potential impact of 24-hour Knowledge Factory paradigm, especially in the context of information systems: Overall, the emerging 24-hour knowledge factory model will allow us to better integrate the contributions of key players from around the world. The example of software development is used in this paper because this type of activity relies primarily on the transfer and creation of knowledge, with minimal infrastructure requirements. Berger has discussed the role of improvements in task modularity and rapid knowledge transfers in enabling globally dispersed teams to work together to achieve a common task [Berger 2006]. The 24-hour knowledge factory represents the evolution of this paradigm to the point where a fully integrated global work model allows constant engagement on tasks, dramatically influencing the manner in which companies design, develop, implement, test, and maintain their diverse repertoire of information system assets.

The efficacy of the above types of knowledge-sharing and global collaboration endeavors is being analyzed through the establishment of research teams spread across multiple continents. For example, researchers at the Wroclaw University of Technology in Poland read a working paper on the 24-hour knowledge factory paradigm, contacted colleagues at the University of Technology in Sydney, Australia; then, they jointly approached the University of Arizona to establish the research project called the 24/7 Virtual Student Exchange (VSX) Teaching and Learning model [Chaczko 2006]. Such geographically dispersed research teams provide one mechanism for studying the broad range of research issues.

Instances of semi-structured work arise in virtually all types of professional endeavors that involve mental work. The scope is diverse, and includes professional work from medical, logistics, product design, finance, accounting, and legal arenas. Further, the work does not have to be office-based.

Part 2: Key Elements and Key Decisions

The concept of 24-Hour Knowledge Factory possesses some overlap with the concept of offshore outsourcing; however, neither is a subset of the other. Agrawal et. Al. describe "round-the-clock shifts" offshore, where some firms even pay higher wages for offshore workers to work odd hours [Agrawal 2003]. Their research showed that companies can reduce costs 30 to 44 percent for many types of work, including R&D, by performing "round-the-clock" shifts at the same location. Kaka presents a spectrum of six models for offshore partners: supplemental staff, turnkey projects, assistance in building centers, build-operate-transfer, assets, and joint ventures [Kaka 2006]. The 24-hour Knowledge Factory model can be viewed as the next logical step in this progression as it involves a focus on knowledge and closer collaboration among the constituent work teams.

The inherent nature of the 24-Hour Knowledge Factory requires closer attention to the issues of task dependencies, organizational structures, team coordination and optimization, decision rationale and history, and transition between shifts. Consider the notion of "cyclic decentralization" or "sequential responsibility" where each collaborating center holds the control

and coordination responsibility for exactly eight hours. The defense forces have traditionally used the notion of sequential responsibility in terms of scheduling individuals at guard posts. Similarly, hospitals use similar concepts with scheduling of doctors and nurses. These examples from diverse sectors provide evidence that one can handle complex operations using shift type operations. However, the task dependencies and the management structures of defense forces and hospitals differ very significantly from each other, and from those in other domains of relevance.

Task Dependencies

Depending on the knowledge domain and the type of activities envisaged to be processed by a 24-Hour Knowledge Factory, one can visualize varying degrees of task dependencies**.** Three pertinent scenarios, depicted in Figure 3, are analyzed for their suitability for different operating environments. It is important to note that these three scenarios are not meant to be discrete – in fact, many real-life knowledge factories will employ a hybrid scenario that incorporates aspects of each. However, for the sake of understanding the structural determinants of decision-making in the 24-Hour Knowledge Factory, it is useful to decompose into these three scenarios.

[INSERT FIGURE 3 ABOUT HERE]

Autonomous Scenario: In this case, shown in Figure 3(a), individuals work relatively independently and do not rely on others for advice in making their decisions. A large number of employees perform work, under a single supervisor, with virtually no need for peer-to-peer interaction among these employees. An example of this scenario is a software support center where customers can call an individual support representative and receive knowledge from that one individual, who, in turn, is supported by a computer-based infrastructure that is continuously updated based on customer queries and experiences. The same concept could apply for support centers that provide assistance on simple legal or taxation matters. The autonomous scenario applies primarily to situations with high degree of inherent structure.

Semi-Autonomous Scenario: In the case depicted in Figure 3(b), individuals still work independently, but occasionally need to consult others. An example of this is a software maintenance engineering team assigned to develop incremental releases to an existing software product. Such a team can work somewhat independently because the changes to the code are primarily isolated bug fixes, but may occasionally need to consult experts, such as the original

developers of the code. Another example of this scenario is the reading of X-rays and other radiological information. Some countries allow such medical advice to be provided from abroad; others do not. In the latter case, a professional based in the patient's country (or even state) may need to formally endorse the medical opinion rendered by a medical doctor in another country.

Tightly Interdependent Scenario: In the scenario shown in Figure 3I, all the individuals need to frequently interact with each other in order to complete the task. When a new software product is being developed, the decisions made by one team member may have impact on many other team members, and may also require the inputs of many other team members. The IS field has witnessed repeated rounds of debates on centralization versus decentralization of IS tasks, functions, and infrastructure; frequently, in cases where the work was decentralized, the different tasks were assigned to different centers who retained ownership and responsibility for a significant period. However, in the case of the 24-Hour Knowledge Factory, the intent is to have each collaborating center maintain control for 8 hours, and then pass the responsibility to a peer center. This places a requirement for creating new IS infrastructures that can provide better abilities for rapid knowledge transfer between these centers.

Organizational Hierarchies

While considering appropriate decision support systems for the 24-Hour Knowledge Factory environment, one must also consider the axis that relates to the nature of the organization. In a flat organization, all decision-makers, regardless of task or geography, can be deemed to belong to a single organization. In other cases, additional layers of hierarchy exist within the overall organization. Based on the degree of importance played by the geography or the task, one can visualize the three cases depicted in Figure 4 as the mechanism to handle decision-support knowledge through either the geographic location or the task group.

[INSERT FIGURE 4 ABOUT HERE]

Flat Organizational Model: Although the flat organization may seem simple, it is the most complex model from the viewpoint of the 24-Hour Knowledge Factory because individuals must consult with the maximum number of other individuals without the benefit of levels of hierarchy to aggregate the various inputs and outputs of their decisions. Consider the scenario where

designers of the software system are located in US, China, and Germany; and testers of the system are located in China and Australia. The stakeholders for the system may be located in other countries and time zones. Designers in US may need to consult testers in China for performance analysis, who may in turn need to consult stakeholders in France for performance measures. In order for the 24-Hour Knowledge Factory practice to succeed in such an organization, one will need to redefine the internal process for making decisions.

Geography Specific Organizational Model: When the existing organization is characterized by hierarchy based on geographic considerations, it is easy to apply the 24-Hour Knowledge Factory paradigm. In such cases, the organization is headed in each country by an individual who is empowered to make major decisions at the local level. As such, many of the decisions can be made at the center level. For example, the Asian office of an automobile company may be empowered to make all decisions related in Asia, including ones related to marketing and advertising. Individuals from this center can then interact with their counterparts in Europe and America, using the 24-Hour Knowledge Factory concept, to create a new marketing strategy with the understanding that the final decisions will be made by the respective management in each continent. This model allows creativity and productivity to be shared across geographies but still adapted to meet the unique needs of various geographies.

Task Specific Organizational Model: In a task-oriented organization, all decisions related to a particular task are made in one department of the organization, irrespective of the physical location of persons of this department. The 24-Hour Knowledge Factory concept is especially geared to suit this type of organizations. Multinational companies like IBM generally use this type of organizational model. Applications involving complex information systems development, creation of financial plans, development of advertising plans, development of new products can all be handled effectively in this case. We believe that an increasing number of companies will adopt this organizational structure over time. The challenge to us in the IS community is to develop IS infrastructures that can support diverse applications in a manner that can transcend both geographic and temporal boundaries.

Team Coordination and Optimization

The use of multiple collaborating centers spread across multiple continents is becoming prevalent at several computer companies. A controlled experiment was conducted, at IBM, to compare the performance of a team working exclusively at one place and another team that involved workers at one location in the US and a second location in India. The two software development teams studied at IBM were virtually identical in all structural respects. Each team had seven core developers, of similarly varying experience and responsibility; they were organized on a task-oriented basis, in terms of the above hierarchy. Both teams were managed by the same development manager, and were observed closely for a period of 52 weeks.

The results of this controlled experiment are interesting. In the co-located scenario, knowledge was held only at one location; but in the distributed scenario, with tasks being interdependent and shared between locations on a regular basis, knowledge was disseminated as a natural part of the process, thereby leading to diversification of knowledge resources. Further, the time taken for resolution of tasks was reduced by nearly 50 % in the latter case. There was an unintended process improvement: with the introduction of the 24-hour development model, the capture of the decision rationale and history became a natural part of the development process, and the tendency of software engineers to avoid or delay knowledge dissemination tasks was overcome. On the flip side, the loss of informal communication was cited as the most significant hurdle. In order to partially mitigate this problem, all the members of the distributed team had an initial face-to-face meeting.

The software industry is taking the lead in adopting the 24-Hour Knowledge Factory model with resources that are distributed, both in spatial and temporal terms. The mobile industry firm, WDSGlobal, utilized Extreme Programming methodology to enable programmers to contribute to the same lines of code in tandem, in a globally distributed, round-the-clock software development project [Yap 2005]. At the outset, the entire team met face to face to get to know and trust each other. Further, explicit pairings were made within the team to build trust. A key conclusion was the need to maintain teams of equal size at each location; otherwise, the location with the largest team will take over the design. They also realized that priorities were changing too quickly; so they decided that managers should reprioritize tasks only once a week in order to make the team most productive.

Motorola is another company that has utilized a similar approach to achieve higher levels of productivity from their software division. A project at Motorola used developers in six countries to develop the same piece of software, with each site maintaining local work shifts. Work was performed on the project, somewhere in the world, for at least 21.5 hours per day [Battin 2001]. Over 500,000 lines of code were developed with minimal synchronous interaction among the different sites.

Decision Rationale and History

As a task is transitioned from one worker to another, one seeks to minimize the time required by the "incoming" worker to become operational. The latter worker needs to know the events that have taken place since the time she or he last signed off. One of the key requirements of the 24-Hour Knowledge Factory paradigm is to provide new methodologies and tools that will allow an individual to understand in (literally!) 16 minutes the work done by others in the preceding 16 hours! For 24-Hour Knowledge Factories to succeed, business processes must be aligned with information systems so that patterns of business knowledge can be reused across processes [Mitra 2006]. Virtually all possible types of endeavors can be categorized using the couple of taxonomies related to tasks and organization hierarchies discussed above. Many of the endeavors involve rapid and coordinated decision making. In order for these decisions to be made in a timely and effective manner, one needs integrated decision support systems to mitigate the spectrum of problems encountered with a geographically and temporally distributed decision making team. In the 24-hour Knowledge Factory, knowledge is passed from one location to another in rapid succession, and must be characterized and structured appropriately to minimize the time required for a worker to absorb the previous knowledge worker's information.

When knowledge is spread over multiple locations and time zones, new IS methodologies and tools are needed to allow knowledge from anyone to be used anytime and anywhere in the process without imposing a significant burden; as such, the knowledge transfer activity becomes a critical aspect of the new IS methodology. Some preliminary tools have now become available in this arena. For example, UMEA is a tool for automatically organizing data objects into collections that are specific to tasks; it is claimed to be simpler and more productive than a file

syst–m - this type of approach reduces the time to navigate through an information repository and makes it possible to locate task specific knowledge on a daily basis as required by the 24-Hour model [Kaptelinin 2003]. The Lifestreams concept of UMEA logs objects and events relative to a project, so that an IS engineer's code can be automatically justified by searching the Lifestreams memory for all objects referenced by the engineer. The benefit of this approach is that prior knowledge is stored in the context of the actual artifact being worked on, so that the worker does not need to leave the context of his or her work to retrieve knowledge related to that work [Fertig 1996]. The notion of time travel as a means of knowledge sharing is a foundational concept of Lifestreams and enables retrieval of information based on logical constraints such 's 'show me the state at the time when I receive an email from 'yz' [Rekimoto 1999]. In the 24-Hour Knowledge Factory model, the ability to introduce time and state as a first-class search parameter for knowledge is important because it allows individuals working on a rapidly-evolving project to revert to a prior day or week if they need to understand the sequence of changes that were made to the project.

When the goal is to share with others in 16 minutes what was done in 16 hours, there is not adequate time to fully explain *how* and *why* the decisions were made. Furthermore, when the individual is performing the work in one time zone, the opportunity to consult the colleague who made certain decisions does not exist. As such, capturing and storing the decision rationale and history in context of the information system is especially vital in the 24-Hour Knowledge Factory where workers collaborate on a project by decomposing the project into subsections that can be performed independently and then merged together on a continual daily basis. Some of the previous projects in this arena have been domain-specific. For civil engineering endeavors, the DICE (Distributed and Integrated Collaborative Engineering Environment) methodology provided a platform for collaborative engineering; it decomposed each engineering project into a set of modules and allowed work to be conducted in parallel on each section of the project [Sriram 1992]. When the system encountered conflicting decisions about a particular design decision from engineers in different modules, it used the design rationale to help negotiate the outcome. The use of such a strategy in the 24-Hour Knowledge Factory would enable workers, especially ones with conflicting solutions to a given problem, to gauge the exact implications of each option on the different stakeholders of the system.

The existing field of design rationale capture tools spans the spectrum from fully unstructured rationale to completely modeled rationale. Minutes of meetings represent an unstructured, time delineated capture of information. QuestMap [2000] and DRAMA [Brice 1998] are examples of the next step – they provide basic structural elements and enable the user to devise a useful structure. At the other end of the spectrum from meeting minutes is DRIM, a system that incorporates a completely specified model for the rationale underlying the design process [Pena-Mora 1995]. Design reuse is an obvious requirement in the 24-Hour Knowledge Factory – the ability to componentize and plug in work done in previous time periods enables the process to progress much faster. Work at the Tsinghua University in Beijing has led to another prototype for using design rationale to support design reuse [Wang-Xin 2001]. The Tsinghua system incorporates multiple intelligent mechanisms to process design rationale information and to relate it to the design of the system. The SPOOL project at the Université de Montréal takes a slightly different approach; it uses reverse engineering techniques to analyze existing projects and to determine which patterns in the design could be used to infer the rationale behind recurring patterns [Keller 1999]. This minimizes the need for the designer to provide the rationale so that the 8-hour period in the 24-Hour model can be spent on producing the core information, rather than on documenting the rationale.

A concept demonstration prototype, called KNOWFACT (from Knowledge Factory), was developed by two of the authors to begin the process of applying these principles directly to the 24-Hour Knowledge Factory by building on existing methodologies and IS tools. This prototype was tested in a real-world situation involving the design of satellites; in this environment, technical decisions regarding the specific design of the system are made on a daily basis, and require constant re-evaluation of the effects of these decisions on a variety of stakeholders who are geographically distributed [Seshasai 2004]. The goal was to attain common understanding of requirements and also of past experiences and behavior; this knowledge of historical facts and issues can enhance the productivity of workers involved in development, testing, and documentation of information systems in the 24-hour knowledge factory.

[INSERT FIGURE 5 ABOUT HERE]

The KNOWFACT decision support system is depicted in figure 4. The Decision Rationale Module (DRM) facilitates the definition of the key attributes that characterize the system for each stakeholder; these attributes form the basis of a utility interview that helps to determine the level to which the present state of the system satisfies the stakeholders (or requirements). From the viewpoint of the manager, DRM provides a structured and consolidated approach that encourages the team to represent only the most important factors that drive the system being produced. The Decision History Module (DHM) captures all the historical information on specific decision parameters; these are aggregated to calculate values for the attributes that were defined for the DRM. The system was designed to incorporate only a small set of aggregate attributes because it has been shown that decomposing a system to a small set of aggregate attributes has a positive effect on human comprehensibility and accuracy in terms of interacting with a decision support system [Bohanec 2004]. Dynamic forms are used for human interaction with the system, based on earlier research that decision support systems with flexible forms that are appropriate to the data being used for decision-making are most useful to decision-makers [Wu 2004]. As the final step of the system, the calculated values for each attribute are incorporated into the utility function to calculate the overall utility measure for the system; this utility measure is used by the team to redefine the set of attributes to use, and also to store the rationale for the decision.

The DHM system is geared to capture, reuse, and better exploit valuable information assets, with the objective of mitigating temporal and spatial barriers in large multi-organizational multidisciplinary endeavors so that each endeavor stands on the shoulders of previous endeavors and projects can easily be transferred between teams. While the creation of most of the documentation of technical changes is automated, the user is prompted to document the rationale when significant changes are made to the design or the implementation. The Decision Rationale Module (DRM) is geared to elicit and capture critical information on the objective of the endeavor, and to analyze and store information about utility characteristics for every stakeholder involved in the particular endeavor. This builds on prior research that suggests that decisions across teams are best made when the decision can be characterized in terms of multi-attribute models and where each attribute represents an aggregated set of characteristics of the system.

DRM allows users to observe links between multiple stakeholders, multiple decision phases and multiple projects, by conducting automated interviews – in a 24-Hour Knowledge Factory, this allows for the opinions of the decision-makers' to be quantitatively incorporated in the process even when they are not available at the same time or place.

Demand Management and Long-term Productivity

A 24-hour knowledge-based model allows for greater management of changing customer demand and time to market by leveraging lower labor costs, providing greater flexibility to reallocate and reassign resources, and enabling end-users and customers to access crucial resources. A good example of the improved demand management is in the area of radiology, where radiologists based in other continents can read X-rays overnight and provide much better care, especially in an industry where the labor supply in the United States is limited. As offshore knowledge workers gain experience and move up the learning curve, they can help to provide for 24 hour availability of high value resources. One example of this phenomenon is a company that employs home-based workers in India to perform medical transcription. As these workers move up the value chain, their home-based work environment continues to allow them to be readily accessible. Accordingly, these workers can work longer hours, as necessary, concurrently with family obligations at home, thereby serving as 'agile' knowledge workers, in the knowledge factory, in real-time.

When moving toward a 24 hour knowledge factory model, factors such as the comparative skill level, the ability to grow in size, quality management, and the use of emerging communications technologies need to be incorporated into the IS infrastructure that is established to serve as the backbone for such factory. The key here is to help transform, not transfer, the work. As the tasks are transformed, jobs will need to be redefined. One appropriate analogy is the "law of the horse" that relates to the impact on horse carriage manufacturers just after the automobile was invented. Initially, the workers building horse-driven carriages saw their jobs vanishing; however, the overall impact on the job market was positive based on the introduction of the automobile; the advent of the disruptive technology forced the horse carriage manufacturers to adapt.

Similarly, the advent of the 24-hour Knowledge Factory paradigm will require pioneers adopting this paradigm to devote significant time, at the beginning of the adoption process, to gathering of requirements, organizing stakeholder workshops, and setting up communication norms, in order to derive major productivity benefits in the long-run.

Part 3: Five Key Research Issues

A number of researchers have looked at various issues of relevance to the 24-Hour Knowledge Factory. While some of this research provides is useful in analyzing the 24-Hour Knowledge Factory paradigm from various vantage points, these researchers rarely treat the global IS delivery system as a knowledge factory, where knowledge is the key component that is produced and traded– this is the research direction that this paper is encouraging. While software is being used as a prime example of this model, the model itself applies to any domain in which knowledge is the core component of production.

In building this 24-Hour Knowledge Factory model, a number of known concepts can serve as valuable building blocks. For example, prior research on optimal plant location for global manufacturing can be applied to the knowledge-manufacturing domain. Similarly, ongoing research on software management practices can be adapted for use in a globally and temporally distributed framework. Further, the growing notion of sourcing work offshore can provide the foundation for discussing the "hybrid" model – where work is shared between onshore and offshore locations.

Table 1 in the Appendix summarizes contributions in areas of relevance to the 24-Hour Knowledge Factory:

Based in part on the literature review summarized in this table and the discussions above, one finds that several areas require further research in order to fully understand, implement, and benefit from the 24-Hour Knowledge Factory model. The key issues are as follows:

1. Collaboration Across Geographic and Temporal Boundaries;
2. Splitting Tasks into Well Defined Components;
3. Assembling Tasks into a Work Product;

4. Reinventing the Work Product based on New Opportunities; and
5. Continuous Feedback, Adaptation and Refinement.

D. While previous research has addressed the above issues, this research needs to be reoriented and expanded to meet the needs of the 24-Hour Knowledge Factory environment, as described in the following subsections

1. Collaboration across Geographic and Temporal Boundaries:

In order to surmount spatial, temporal, and other kinds of boundaries, Gupta [2001] has advocated a four-faceted knowledge-based approach that places emphasis on:

- Knowledge Acquisition, or tapping traditional systems to provide accurate and comprehensive material for the new knowledge-based systems;
- Knowledge Discovery or automated mining of numerical, textual, pictorial, audio, video, and other types of information, to capture underlying knowledge, either on a one-time basis or on a continuous basis;
- Knowledge Management to deal with different types of heterogeneities that invariably exist when inputs have to cross-over borders of different types (national, organizational, departmental, and other); and
- Knowledge Dissemination to extract, customize, and direct knowledge to appropriate departments and users, based on their individual needs.

The literature, summarized in Table 1, includes efforts in the field of collaborative knowledge management and coordination across different locations. Almost all prior research in this area focuses on collaboration that needs to occur on an occasional basis, typically once a month or maybe once a week. In the case of the 24-Hour Knowledge Factory, such collaboration needs to occur on a continuous basis, with an additional surge of information being shared at every 8 hour intervals. As such, further research is required to assess the specific requirements for collaboration in the 24-Hour model, to build IS tools that will meet these requirements, and to incorporate techniques for knowledge manipulation and enhancement. The design rationale and history modules presented earlier in this paper can serve as one foundation for the proposed research – these modules provide collaborative capabilities for the 24-Hour Knowledge Factory model that is characterized by the actors being distributed over space and time, and being unable to consult each other on a face-to-face basis to share rationale and history. Research in the areas

of knowledge acquisition, knowledge discovery, knowledge management, and knowledge dissemination should also give emphasis to the fact that the collaborating individuals have minimal overlap in terms of their respective workdays, and the knowledge processing aspects should not add undue overhead on the concerned individuals.

2. Splitting Tasks into Well Defined Components:

In our case of 24-Hour Knowledge Factories, one needs to define how to decompose information system projects and other types of professional endeavors into a series of tasks that can be individually performed by a professional, without having to know most of the idiosyncrasies of other tasks. Is it practical to make this decomposition, when the concerned persons are located thousands of miles from each other? In the book referenced earlier, Berger describes multiple evolutions of technology that have seen the splitting of tasks as the catalyst for new work models and new technologies. For example, the IBM System 360 represented the disaggregating of the mainframe hardware from the software logic, thereby allowing separate workers to add value to each component separately and without knowledge of each other's work. Similar models can be identified within the software industry – operating systems allow software programs to be produced without knowledge of the underlying operating system; object-oriented programming is built on the notion of separation of tasks into self-defined objects that do not need to share their implementation with other objects in order to be used. On a broader level, the field of "component-based software" has attempted to address this need by decomposing a software endeavor into a series of components.

How can this concept be extended to other white-collar professionals in business, medicine, or transportation? Can we develop a generic IS-based infrastructure that can be applied to diverse industries and applications, or do we have to adapt the new paradigm to suit the requirements of specific project, company, or industry? While the concept of decomposing major endeavors into a series of discrete tasks has been embraced by part of the information systems communities and by sections of few other communities, we need to broaden this vision to include many diverse types of professional activities. IS can potentially provide the tools and the mechanisms to achieve this objective, and we need to address this opportunity from a sustained research perspective.

3. Assembling Tasks into a Work Product

Further research is required to determine models for assembling the products of individually completed tasks into an aggregated work product that is marketable as a product or service. The literature review covers a set of principles that were useful for the manufacturing industry in terms of creating an assembly line and distributing the assembly line over multiple plants at multiple locations. The goal in the manufacturing industry was to take a set of individually created but standard physical parts and reassemble them into a complete product. In the 24-Hour Knowledge Factory model, the individual piece components are not necessarily going to be standardized. As discussed above, the model provides the ability to allow individual artisans to produce unique pieces of work. Furthermore, the work artifacts are produced on a daily basis and need to be assembled in a very short timeframe at the beginning of the work day in order for continued work to occur.

Returning to the software industry examples presented earlier, the assembly of tasks into work products is a concept that has been present in software for years. Once software was separated from hardware in the IBM System 360, it became possible to produce offerings that combined various pieces of hardware and software together as a bundled offering without the designers of the key components knowing in advance that the specific combinations were to be produced. Similarly, the field of software – especially open source software – is able to pull components from different workers and plug them together without the original developers having planned for such cases of specific use.

One factor working in favor of assembly is that the artifacts being produced are knowledge-based, rather than physical in nature. Thus, the logistics of transferring and reconnecting the knowledge-based work artifacts are easier to mitigate than in the case when physical parts need to be transported and reassembled. A second factor that works in favor of assembly is that the tasks will be defined in terms of standard inputs and outputs, so that the worker does not need to know the inner workings of the knowledge product during the process of assembly. Returning to the example of component-based software, if individual software developers produce individual units of code in separate time zones and geographies, the assembly process is easy, provided the

developers are using standard software interfaces to define the functions and methods being created. Unlike physical parts and subsystems on assembly line, the software components can be combined in a variety of forms that do not even need to be prescribed at the time of creation.

Research in this area is needed to adapt concepts and principles from the manufacturing industry, and to apply them to the knowledge arena. As physical assets are replaced with knowledge-based assets, the frequency of reassembly is much higher, and the final products must possess the potential to incorporate varying sets of componentized products outside of a purely linear assembly process. The evolving IS infrastructure should leverage previous research, such as the vision that led to the concepts of operating systems and machine independent programming languages, to help conceive of new ways to combine the fundamental components of work in different professions to provide new services and capabilities using the same skills.

4. Reinventing Work Product based on New Opportunities

One of the exciting possibilities with the 24-Hour Knowledge Factory is to create new work products and services that are made feasible through the coordinated deployment of a geographically and temporally distributed workforce. This paper has previously alluded to the example of specialized artisans being able to produce and market custom work at attractive prices, thereby undoing the strong focus on generic products that characterized the post-Industrial Revolution era. Significant research needs to be performed to determine how the componentized tasks described in key issues 2 and 3 can be delineated to the end customer, in a manner that would enable the customer to request the desired work product based on available components. For example, a 24-Hour Knowledge Factory in the software industry may involve a development team in a foreign country, which has an understanding of the local business culture. By having the foreign country's development team review the individual pieces of the work-in-progress on a daily basis, one could refine the software to address subtle cultural differences at a level of granularity that would not be feasible at the high-level design phase. This type of "automatic" redefinition of the work product could expand the potential market in which the product would be able to sell; and other types of professional endeavors need to embrace this concept too.

Another example of work product redefinition is in terms of taking advantage of the temporal distribution and the continuous engagement on tasks. If a 24-hour model were used to satisfy a client request for a particular software deliverable, daily input could be provided by the client on a working prototype of the final product. Work produced in other time zones, when the client was sleeping, would be presented to the client in the morning, and a local team would be available to receive synchronous feedback from the client on the daily deliverable. This input could be incorporated directly into the process by the local team and communicated in the daily knowledge transfers to the other teams, thereby providing feedback on a daily basis. Although this type of daily feedback may be possible if the development team was localized but simply in a different time zone, the 24-hour model can allow for the powerful combination of synchronous and asynchronous engagements that could result in customized work products that are delivered on a daily basis, rather than on a weekly or monthly basis. Further research is needed to analyze the efficacy of this approach for various types of knowledge-based endeavors in different industry segments, and the corresponding needs for IS in each case.

The implementation approach for a company intending to embrace the 24-Hour Knowledge Factory model is envisaged as follows:

- Assess the firm's projects with respect to the task and hierarchy taxonomies presented in Part 2 of this paper.
- Assess the firm's decision rational and history system with respect to the information management framework.
- Redefine the projects and systems identified in Steps 1 and 2 to take advantage of the 24-hour work model. The decision to build a 24-hour knowledge factory will be based, not on a current state analysis of the firm's systems, but on a dynamic redefinition of systems to match the global delivery model that is likely to yield the best results for the firm.

D. Further research is also required into how the traditional waterfall model can be adapted to support the new work paradigm.

5. Continuous Feedback, Adaptation, and Refinement

While the area of continuous feedback, adaptation and refinement bears some overlap with the discussion in the prior section of daily feedback from a client, the focus here is on internal improvement to the processes by which knowledge-based work is conducted. The design rationale and history modules presented earlier in this paper and the related research by others in these areas presume that earlier workers were able to understand, at least partially, the importance of transferring knowledge between actors in a knowledge-based environment. The 24-hour knowledge factory presents a need for *continuous* transfers to occur and opens a new area of research for supporting concurrent and continuous activities related to: feedback from stakeholders; adaptation of the product, service, or endeavor; and refinement of domain-specific decisions. The models available today do not allow for significant time to be spent on collecting the information, discussing the information, and acting upon the information. Processes used within the 24-hour knowledge factory model must automatically process feedback, and be capable of self-adaptation and refinement, with minimal involvement from individual workers. Instead of a generic solution for all industries becoming available, it may be necessary to develop multiple approaches to cater to the idiosyncrasies of different industries and applications. This requires additional research to be performed, especially in terms of conceiving new IS approaches to create IS infrastructures that will serve as the backbone for the 24-Hour Knowledge Factories for different sectors of the global economy.

The five key research issues discussed above have significant overlaps with specific aspects of extant research that were identified in Table 1. Each of these five key areas shortlisted for sustained research possess aspects that have been historically addressed from a different perspective, such as work in new product development, analysis of plant location options or under the more generalized rubric of Organizations and Information Technology. In Table 2 (shown in Appendix), we link the five key areas of research discussed above to relevant prior work that was identified in Table 1.

Part 4: Conclusion

The 24-hour knowledge factory model is an emerging model that requires focused research to meet the rapidly changing needs of information systems practice across a broad range of knowledge-based industries. The concept employs a global delivery model in which members of

a globally dispersed team work on information systems or other knowledge-driven endeavor around the clock; each member of the team works during the normal workday hours that pertain to his or her time zone. At the end of such a workday, a fellow team member located in a different time zone continues the same task. The 24-hour knowledge factory paradigm holds the potential for significantly reducing the elapsed time and total costs of IS and domain knowledge-based endeavors. In order to accomplish this objective, one needs to undertake sustained research on a broad set of technical and non-technical issues that have been delineated in this paper. Further, such research is likely to provide good potential for the creation of research endeavors that involve colleagues in three or more continents around the world.

The 24-Hour Knowledge Factory will ultimately allow individuals to work anywhere in the world, either in an office environment or in a home environment. Accordingly, these workers can work longer hours, as and when necessary, concurrently with family obligations at home, thereby serving as 'agile' knowledge workers, in the knowledge factory, in real-time [Malhotra 2004].

When moving toward a 24 hour knowledge factory model, factors such as the comparative skill level, the ability to grow in size, quality management, and the use of emerging communications technologies need to be incorporated into the IS infrastructure that is established to serve as the backbone for such factory. The key here is to help transform, not transfer, the work. As the tasks are transformed, jobs will need to be redefined. When the automobile was invented, workers building horse-driven carriages initially saw their jobs vanishing; however, the overall impact on the job market was positive; the advent of the disruptive technology forced the horse carriage manufacturers to adapt. The same will happen over time as new IS approaches allow semi-structured professional work to be conducted in a much more effective manner. One needs to make investments now, in order to realize major productivity benefits in the long-run [Swadia 2004].

In order to ultimately create an integrated archipelago of knowledge-based assets, as well as to address the individual needs of an increasingly diverse set of users, one needs to provide effecti“e "on-off ramps" to the emerging information highways by drastically enhancing the

ability to engage human resources across the globe in a seamless manner. Continued exploration of such issues will lead to a new optimal balance in the service arena; this could be similar to the balance attained in the manufacturing arena. In the end-scenario, the success of companies, even nations, will be determined largely by their ability to coordinate and manage such collaborative endeavors on an agile and global basis.

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Appendix Of Tables and Figures

Author	Title	Contribution
Information Technology Management		
Carmel and Agarwal, 2002	The Maturation of Offshore Sourcing of Information Technology Work	Separability of software production has reduced transaction costs for coordinating IS work.
Taylor and Bain, 1999	An Assembly Line in the Head	"White collar factory" requires employment relationship concepts from the factory.
Drucker, 2002	They're not employees, they're people	Talent management should not be outsourced.
Aron and Singh, 2004	IT Enabled Strategic Outsourcing	IT work is on a knowledge continuum, and information workers are vital at each stage.
Elenkov, 1998	Can American management practices work in Russia?	Management practices in America cannot always be transferred without cultural understanding.
Johnson, 2001	Learning from toys	Toy manufacturing and software have similar customer demand and product lifecycle – toys are outsourced for risk management.
Carmel and Agarwal, 2001	Tactical Approaches for Alleviating Distance in Global Software Development	Software development projects in the future will involve separated centers of IS professionals spread

		around the world with individuals dispersed remotely.
Knowledge Management		
Lei and Slocum, 1992	Global strategy, competence building and strategic alliances	Alliances between sites must understand and share core competencies.
Tallman, 2002	Internationalization globalization and capability based strategy	Capability based theory should be used to leverage process and knowledge-based global networks.
Powell, 1998	Learning from collaboration: Knowledge and Networks in Biotech and Pharma Industries	Knowledge creation is a core competency – it requires collaboration
Davenport, 1998	Managing customer support knowledge	Managing customer support knowledge is vital – one cannot replace human input with automation.
Quinn, 1999	Strategic outsourcing - leveraging knowledge capabilities	One needs to manage knowledge and to eliminate duplication of effort.
Gupta, 2001	A Four-Faceted Knowledge Based Approach to Surmounting National and Other Borders	Sharing knowledge across borders requires focus on knowledge acquisition, knowledge discovery, knowledge management, and knowledge dissemination.
New Product Development		
Porter, 1986	Changing patterns of International Competition	Location coordination is key; configurations of firms vary very significantly.
Earl, 1996	The risks of outsourcing IT	Risks of distributed new product development are organizational learning loss and innovation.
Grandstand et al, 1997	Multi-technology corporations: Why They Have Distributed Rather than Distinctive Core Competencies	One needs to focus on diffusing technological competencies between groups.
Magretta, 1998	The Power of Virtual Integration: An Interview with Dell Computer's Michael Dell	Dell has used advanced technology to coordinate different parts of the supply chain.
Plant Location		
Lovelock, 1996	Developing global strategies for service businesses	Suggests applying lessons from manufacturing to services, by understanding global drivers such as location choice.

MacCormack et. al., 1994	The New Dynamics of Global Manufacturing Site Location	Strategic considerations, such as local skills, are important in building more flexible and efficient plants
Bartmess and Cerny, 1993	Building competitive advantage through a global network of competencies.	Capability focused plant location analysis is applied to manufacturing; and the three important decision criteria are: complexity, diffuseness, and well-developed interfaces.
Venkatraman, 1997	Beyond outsourcing: Managing IT Resources as a Value Chain	Locations should be seen as value centers, with the specific source of value for each center being explicitly identified by service, investment, cost, and profit.
Seitz and Peattie, 2004	Meeting the closed-loop challenge	In a globally distributed factory environment, information management is important for the entire lifecycle of the product.
Blaxill and Hout, 1991	The fallacy of the overhead quick fix	Companies need to transform manufacturing processes for long-term success, not just cut costs.
Pisano, 1995	The new logic of high tech R&D.	Knowledge-based companies cannot just invest in innovative R&D and outsource manufacturing – they need to invest in the manufacturing process too.
Organizations and IT		
Venkatraman and Subramanian, 2002	Theorizing the Future of Strategy: Questions for Shaping Strategy Research in the Knowledge Economy.	Future research on strategy and competitive advantage should focus on individuals, intellectual capital, and relationships between individuals.
Kirsch, 1997	Portfolios of Control Modes and IS Project Management	Combination of informal and formal modes of control are necessary for IS management.
Venkatraman, 2004	Offshoring Without Guilt	One needs to build systems that leverage global talent with individuals around the world.
Orlikowski, 2002	It's About Time: Temporal Structuring in Organizations	Temporal structures are defining characteristics of organizations that lead to further understanding of these organizations.
Sambamurthy	Shaping Agility through	IT investments are indeed key

et. al., 2003	Digital Options: Reconceptualizing the Role of Information Technology in Contemporary Firms	influencers of firm performance along with factors such as agility and capability-building.
Mizoras, 2004	In House versus Outsourced	Workforce and rework dynamics make outsourcing challenging; as such, organizations need third-party firms whose competency is purely in building organizations.
Champy, 2003	Is technology delivering on its Productivity Promise?	Describes X-engineering model for changing organizational relationships by introducing transparency, standardization, and harmonization
McFarlan and Nolan, 1995	How to manage an IT outsourcing alliance	Organizational learning is one major factor in building flexible offshore models.
Lacity et. al., 1995	IT outsourcing: maximize flexibility and control	Organizations should focus more on continuous learning, rather than the debate on strategic offshoring versus commodity offshoring.
Fuchs, 2000	Strategic integration: Competing in the Age of Capabilities	Highlights need to align product-market focus, resources and capabilities, organizational culture, and direction.
Begley and Boyd, 2003	The need for a corporate global mind-set	Emphasizes need for a global mind-set and not being dependant on single country or culture in terms of critical factors for making business performance decisions.
Emerging Facets of Offshoring		
Slaughter and Ang, 1996	Employment Outsourcing in Information Systems	Offshoring adds flexibility to IS work force arrangements but needs to incorporate understanding of economic, legal, organizational impacts.
Saunders et. al., 1997	Achieving success in IT outsourcing	Technical capability is a greater driver than cost savings; core functions should be maintained onshore to preserve this technical capability.
Barney, 1999	How a firms capabilities affect boundary decisions	Transaction cost economics is the only factor in determining whether to keep tasks within company boundaries.

Carr, 2004	In-praise-of-walls	Offshore models cannot just modularize tasks; also emphasizes the need to build strategic competencies in all locations for all tasks.
Christiansen, 2001	The past and future of competitive advantage	Three factors always exist for competitive advantage: economies of scale and scope, integration and non-integration, and process-based core competencies.
Light, 2003	Cross-cultural lessons in leadership	Managers must understand cultural values of themselves and their employees in all locations in order to be successful.
DiRomualdo and Gurbaxani, 1998	Strategic intent for IT outsourcing	Improvements to information systems, business impact, and generation of new revenue serve as guidelines for decisions on offshoring.
Young, 1985	Global competition - the new reality	U.S. needs to try harder to compete globally, because citizens in the U.S. cannot give up their standard of living.
Integrated Value Chain		
Kumra, 2003	The next hurdle for Indian IT	Advocates distinguishing between activities that require proximity to the customer and activities that can be done remotely, and then distributing the tasks accordingly.
Kern et al, 2002	The winner's case in IT outsourcing	Relationship management is the key to outsourcing ventures, because the situation almost always changes from what was initially planned.
Useem and Harder, 2000	Leading laterally in Company Outsourcing	Management styles should involve negotiating results rather than issuing orders.

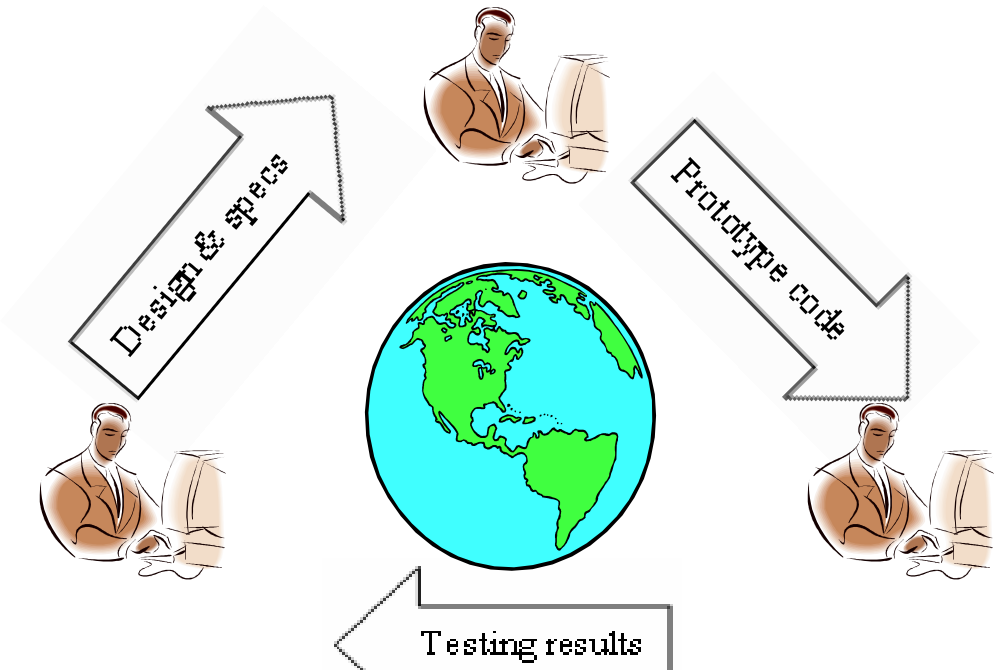
Table 1. Summary of Relevant Literature

	Extant Research That is Relevant to 24 Hour Knowledge Factory						
	Information	**Knowledge**	**New**	**Plant Location**	**Organizations and**	**Emerging Facets of**	**Integrated Value**

	Technology Management	Management	Product Development		IT	Offshoring	Chain
Collaboration Across Geographic and Temporal Boundaries		✓	✓		✓	✓	✓
Splitting Tasks into Well Defined Components	✓					✓	
Assembling Tasks into a Work Product							✓
Reinventing the Work Product based on New Opportunities			✓	✓		✓	
Continuous Feedback, Adaptation and Refinement	✓	✓			✓		

Table 2: A Summary of Extant Research and The Key Areas of Research Going Forward.

Figure 1: A distributed factory with software design operations in three countries around the world.



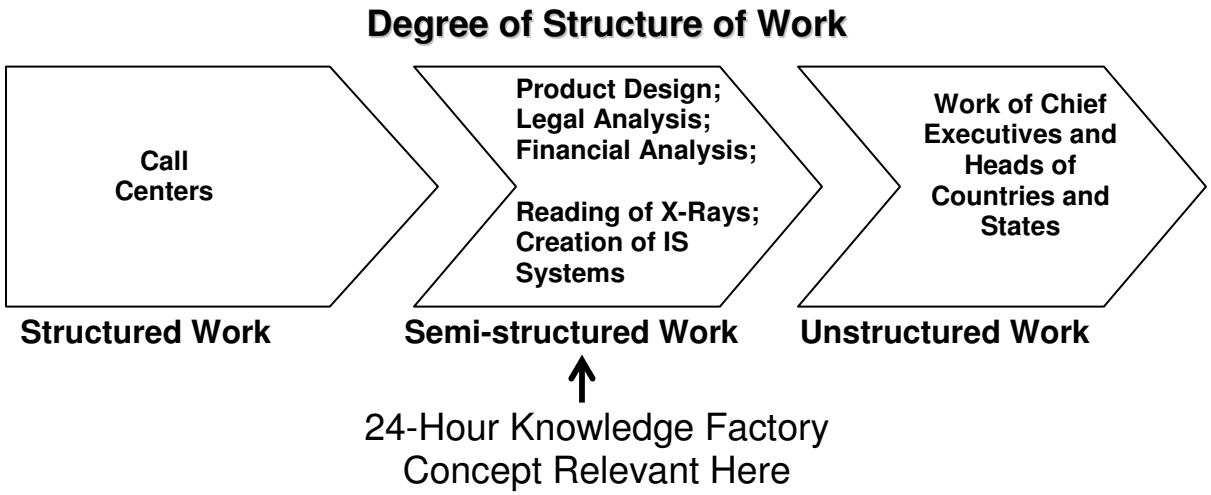


Figure 2: 24-Hour Knowledge Factory Concept Applies Primarily to Semi-Structured Professional Work

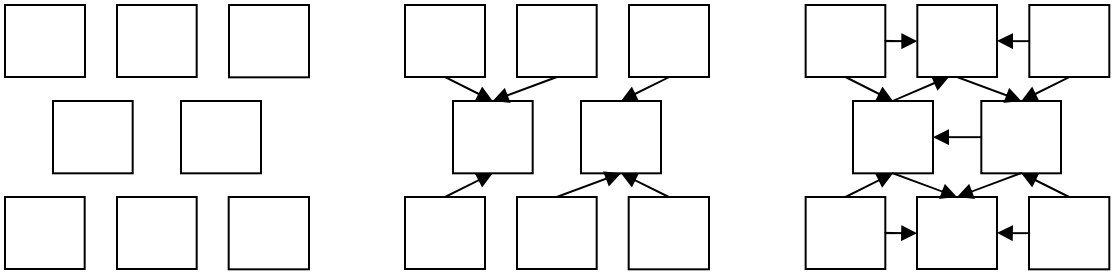


Figure 3: Decision-making dependencies for individual work: three scenarios

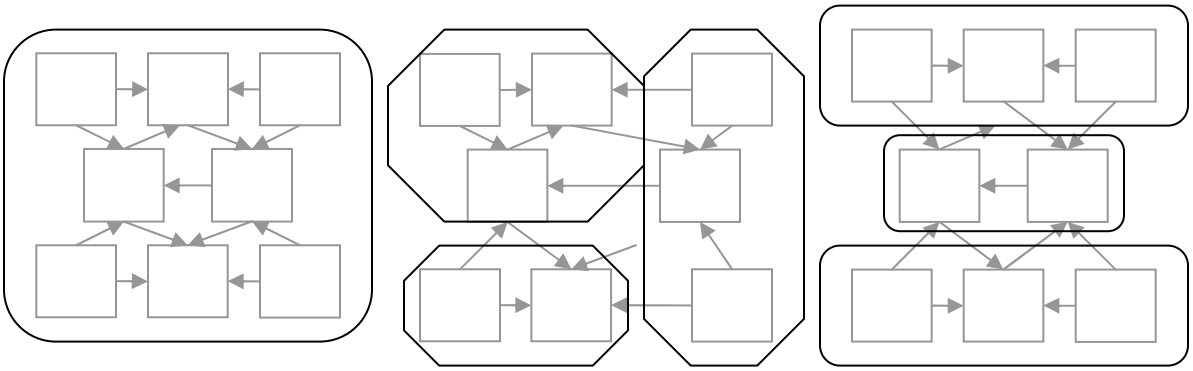


Figure 4: Organizational models for heavily interdependent decision-making teams.

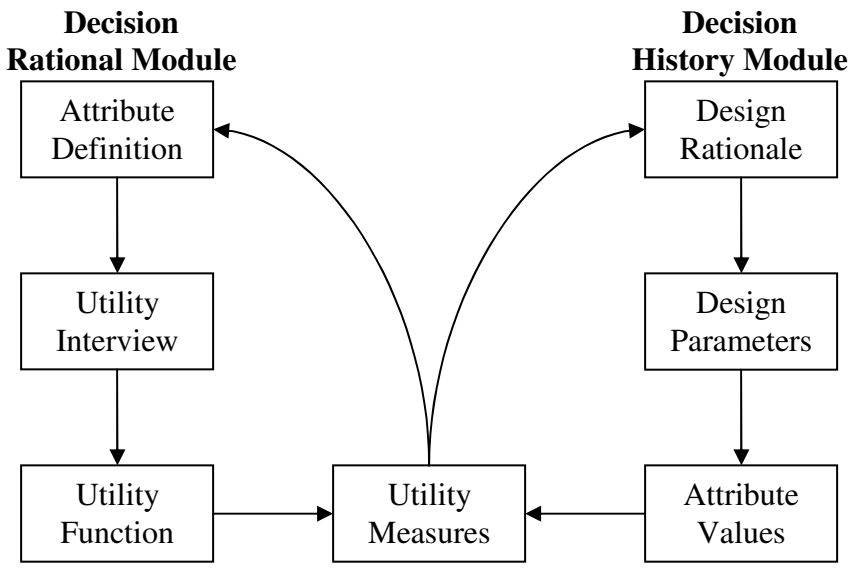


Figure 5: Architecture diagram for KNOWFACT paradigm