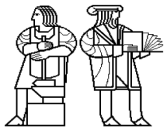

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THE 24-HOUR KNOWLEDGE FACTORY PARADIGM:

THE EVOLVING MODEL FOR OFFSHORING BASED ON STRATEGIC, ECONOMIC, LEGAL, HEALTH, TECHNICAL, AND OTHER CONSIDERATIONS

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Abstract

The 24-Hour Knowledge Factory paradigm involves 3 (or more) collaborating centers, each located in a different continent. Individuals at each center work from 9 am to 5 pm in that country, and then pass the work-in-progress to the next collaborating center to enable round-the-clock performance in a manner somewhat akin to the deployment of three shifts in the manufacturing sector.

The gradual adoption of this paradigm is motivated by several considerations. In late 2007, the World Health Organization concluded that working at night is a probable cause of breast cancer in women and prostate cancer in men. Attempts by US state governments and even the federal government to discourage outsourcing are unlikely to succeed for multiple reasons, and the notion of "hybrid outsourcing" will gain momentum over time. Plus there are the advantages of developing products and services in shorter timeframe; further these products and services can command broader appeal in the global marketplace. A detailed study was conducted at IBM to compare the performance of a co-located team and a distributed team, and the performance of the latter team exceeded initial expectations.

The 24-Hour Knowledge Factory is relevant for structured and semi-structured applications in many knowledge-based industries including accounting, legal, design, and development. There is a growing array of examples from healthcare and other domains where off-site professionals have been able to provide better results than on-site professionals, thereby validating that many tasks can be more effectively performed using the 24-Hour Knowledge Factory approach.

Introduction

Towards the end of 2007, the World Health Organization and the American Cancer Society determined that working at night is a cause of prostate cancer in men and breast cancer in women (www.msnbc.msn.com/id/22026660). This was the first time that work schedule had been linked to cancer by reputed health organizations. Earlier, when mines and asbestos were linked to medical problems, countries and companies worked towards minimizing the number of persons who worked in such environments. Similarly, over time, many knowledge-based tasks will be transformed so that the individuals will need to work during daytime only, but the work is conducted at different places around the world (Gupta 2009a). Today, about 20 % of the white-collar workforce in developed countries works during night hours; this number will gradually decrease in coming years and will involve the surmounting of national, organizational, and other types of barriers through the use of emerging approaches for knowledge acquisition, knowledge discovery, knowledge management, and knowledge dissemination (Gupta 2001). This thrust is manifested in the 24-Hour Knowledge Factory paradigm that involves 3 sets of workers, in different continents, each working during daytime in their respective countries and passing over the work-in-progress to the next collaborating center, in order to provide round-the-clock operations and to offer a more efficient organization of work (Gupta 2009b).

Two kinds of environments need to be analyzed. One is the design, development, and implementation of information systems in a manner that leverages the 24-Hour Knowledge Factory paradigm. The other is the development of new information system approaches that will enable this paradigm to be applied to a broad range of white-collar activities ranging from medical services to logistics planning, and from accounting to legal services. We use experimental results from the first environment to make projects for the second environment; the latter is much broader in scope and much bigger in size.

Early Examples and Relevant Work of Others

The roots of the 24-Hour Knowledge Factory can be found as far back as the Industrial Revolution. Before the advent of work standardization (in this case, the dissociation of ‘parts’ from ‘finished goods’), when final products were made from the beginning to the end by one artisan, each item was considered to be a singular piece of art – that is, each product was unique. By breaking production tasks down to simple, componentized activities, productivity attained new heights as artisans became employees and specialization abounded. For example, a gun could be produced by a logger, a blacksmith, and an ammunitions producer, rather than have all three functions performed by one person. Further, each of these subtasks could be performed using a shift system in which persons of one specialization passed the work-in-progress from one person to another.

The advent of electronic computers, coupled with help from diminishing telecommunications costs, allows for the establishment of multiple "factories" in differing time zones, transcending physical barriers. This is exemplified by the notion of 24-hour call centers. Utilizing the earth's natural rotation, we can ensure that employees of call centers can respond to calls that come during normal daytime work hours applicable to their respective locations by creating 3 to 4 call centers in time zones that are 6-8 hours apart from that of neighboring call centers. This concept of multiple support centers has been gradually adapted to support global communications networks. Similarly, semiconductor chip designers who might otherwise be forced to work at odd hours of the night may now work during normal daytime hours in their own countries, avoiding the "graveyard shift" and the accompanying fatigue. The implications of such a work structure are great: many industries may be changed through the utilization of professional service teams in a manner that is not limited by the traditional geographic and temporal constraints.

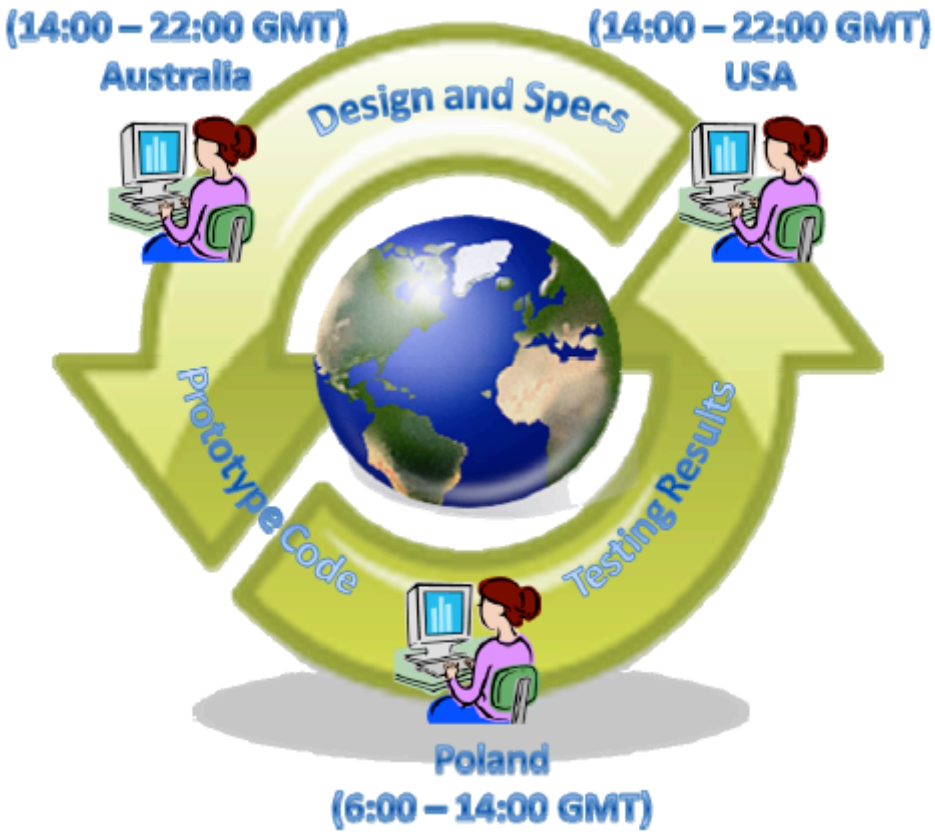

Figure 1: A 24-hour Tri-Foci Scenario.

Software development usually entails a work style denoted by the transmission of knowledge between members of a development team to create a product. Figure 1 shows a conceptual knowledge factory with distributed software design operations located in three different countries around the world. In such a delivery model, a different subtask is assigned to

knowledge workers at each geographic location. This has the effect of improving the overall efficiency of the project, as workers in each location perceive that progress is made "overnight" while they are asleep.

Several researchers have looked at different issues related to the creation of globally dispersed teams that perform knowledge-based tasks, and some of their findings are summarized in Table 1.

Table1: Key Findings of Previous Researchers on Performance of Globally Dispersed Teams

Reference	**Key Point**	**Relevance to the 24-hr Knowledge Factory**
Clark and Wheelwright (1992)	Motorola's virtual team project was completed in half the time and with higher quality, by focusing on lesson reuse from previous efforts.	The concept of lesson reuse can be applied to global teams involving multiple sites.
Chandler (2001)	Roles on a virtual team were defined without regard for remote versus local.	Roles can be shared or distributed globally without distinction between remote and local sites.
Godart, et al. (2001)	The pros and cons of implicit (voluntary) versus explicit (forced) coordination are debated. Implicit coordination involves minimal impact on work methods, whereas explicit coordination fosters better tracking and reuse.	Implicit coordination becomes explicit coordination when it is part of the daily schedule.
Ramesh and Dennis (2002)	"Object oriented team" – decoupled virtual teams that communicate only inputs and outputs.	Knowledge sharing offers the potential to break barriers to decoupling teams.
Sepulveda (2003)	Pair programming with remote and local developers eliminated bureaucracy but negatively impacted culture.	Pair programming concept can be extended to three or more sites and individuals.
Xiaohu, Bin, et al. (2004)	Global units owned their own modules, and there was no discussion between them	Global distribution can lead to situations where the need for knowledge sharing is

	except on inputs and outputs.	reduced, and each site possesses knowledge on its own subsets of modules.
Ishizaki (2005)	Fujitsu provided 24/7 support by combining local teams, continental teams, and a global team to handle mission-critical systems.	A global team can partially replace the need for local teams by frequent sharing of knowledge.
Yap (2005)	The study of a global, round-the-clock development project, with collective ownership of individual pieces of code, provides validation of concept.	Collective ownership is the key to passing work items around the clock daily.
Babar, Kitchenham, Zhu, Gorton and Jeffrey (2006)	The use of groupware support to evaluate software architecture can enhance efficiency over multiple geographical areas.	Using groups in different geographical regions can accelerate the end result.
Jalote (2006)	Project tasks must be carefully assigned in order to derive full advantage of the 24-hour software development model.	Productivity of global teams is critically dependent on proper assignment of tasks to globally dispersed sites.
Cusumano (2008)	Different countries around the world can be assigned responsibility for different aspects of software development.	The assignment of different roles to different sites can, in some cases, lead to higher productivity.

In addition to the above, the vision of the 24-Hour Knowledge Factory builds up on previous work in several allied areas such as information technology management, knowledge management, new product development, plant location, organizations and IT, and offshoring,. Some of the relevant papers and their key contributions are summarized in Table 2.

Table 2: Research in Allied Areas

Author	Title	Key Contribution
Information Technology Management		
Taylor and Bain, 1999	An assembly line in the head	"White collar factory" requires application of employment relationship concepts from

		the factory environment.
Carmel and Agarwal, 2001	Tactical approaches for alleviating distance in global software development	Future software development projects will involve geographically separated centers of IS professionals spread around the world.
Carmel and Agarwal, 2002	The maturation of offshore sourcing of information technology work	The unbundling of software production tasks has reduced transaction costs for coordinating IS work.
Aron and Singh, 2004	IT enabled strategic outsourcing	IT work is on a knowledge continuum, and information workers are vital at each stage.
Powell, Piccoli, and Ives, 2004	Virtual teams: a review of current literature and directions for future research	While information technologies provide the means to support virtual teams as an alternative organizational form, it is the management of these technologies that determines the success of these virtual teams.
Knowledge Management		
Lei and Slocum, 1992	Global strategy, competence building and strategic alliances	Alliances between sites must understand and share core competencies.
Powell, 1998	Learning from collaboration: Knowledge and networks in biotech and pharma industries	Knowledge creation is a core competency – it requires collaboration.
Quinn, 1999	Strategic outsourcing - leveraging knowledge capabilities	One needs to manage knowledge and eliminate duplication of effort.
Gupta, 2001	A four-faceted knowledge based approach to surmounting national and other borders	Sharing knowledge across borders requires concurrent emphasis on knowledge acquisition, knowledge discovery, knowledge management, and knowledge dissemination.
Tallman, 2002	Internationalization, globalization and capability based strategy	Capability based theory should be used to leverage process- and knowledge-based global networks.
Nicholson and Sahay, 2004	Embedded knowledge and offshore software development	The distribution of work across countries for offshore software development requires effective management of knowledge.
New Product Development		
Grandstand et al, 1997	Multi-technology corporations: why they	One needs to focus on diffusing technological competencies between groups.

	have distributed, rather than distinctive, core competencies	
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		
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.
Lovelock and Yip, 1996	Developing global strategies for service businesses	Suggests applying lessons from manufacturing to services, by understanding global drivers such as location choice.
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.
Organizations and IT		
Kirsch, 1997	Portfolios of control modes and IS project management	Combination of informal and formal modes of control are necessary for IS management.
Champy, 2003	Is technology delivering on its productivity promise?	Describes X-engineering model for changing organizational relationships by introducing transparency, standardization, and harmonization
Venkatraman, 2004	Offshoring without guilt	One needs to build systems that leverage global talent with individuals around the world.
Emerging Facets of Offshoring		
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.
DiRomualdo and Gurbaxani,	Strategic intent for IT outsourcing	Improvements to information systems, business impact, and generation of new revenue serve as guidelines for decisions on

1998		offshoring.
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.

Prototyping Efforts

KNOWFACT: The term "24-Hour Knowledge Factory" was coined in 2004 as an extended version of an earlier concept demonstration prototype system called KNOWFACT, which was derived from the words "Knowledge Factory." KNOWFACT was designed to reduce the time and effort involved the design of satellites. In the latter environment, each satellite was designed as a piece of art, and knowledge gained during one design experience was rarely utilized in subsequent endeavors. Further, design decisions have to be made on a daily basis. These decisions impact a broad spectrum of stakeholders who are geographically distributed and whose reactions may lead to reappraisal of the design decision, and possibly to a reversal of that decision. KNOWFACT was designed to enable all stakeholders to achieve a common understanding of requirements and also of all relevant historical facts and issues. The stakeholders came from different backgrounds, and had different priorities in terms of the design of the satellite; accordingly, they had interest in different attributes of the satellite.

In KNOWFACT, the goal was to capture two kinds of information in great detail; the first was related to the history of all decisions, and the second was related to the rationale of each and every decision made by members of the design team, as shown in Figure 2. The Decision History Module (DHM) was designed to capture all the historical information on specific decision parameters with no or minimal human involvement; the different pieces of information were aggregated together, as needed, for purposes of analysis and presentation, so that the human designer could see the information at different levels of aggregation. In contrast, the Decision Rationale Module (DRM) was designed to record information on why specific decisions were made. The values calculated for each attribute were entered into the utility function to calculate an overall system utility measure; this utility measure was used by the team to redefine which attributes to use, and also to store the decision rationale on an evolving basis. Some of these decisions were based on rule-based online interviews with the stakeholders. The questions asked in these interviews were dynamic in nature, and mimicked the technique used by ophthalmologists when trying to decide the power of the glasses to correct a patient's vision. At each stage, the person was asked to choose between two options, and the exercise was conducted to converge on critical decisions relating to the design of the satellite.

The online repository of information was made accessible to all groups—not just for the work in progress, but for future use as well. This concept demonstration system demonstrated the viability of complex endeavors being transferred easily between teams, without requiring each

team to invest time in transferring the knowledge of previous projects and without bothering about spatial and temporal separations between different members of the team. The system allowed everyone to look at decisions made on earlier projects that involved decisions on similar issues. One representative claimed that the prototype allowed him to complete a particular task in one-fiftieth of the usual time.

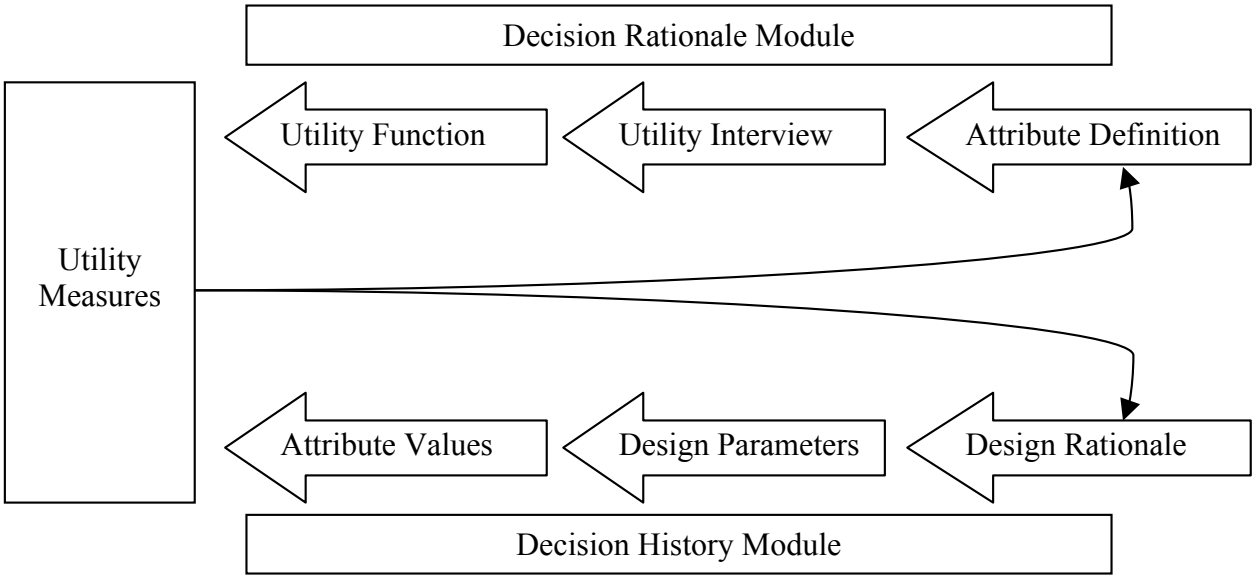

Figure 2: Architecture Diagram for KNOWFACT Paradigm.

CPro and Composite Persona: The above research served as the foundation for developing CPro, a process addressing the operation of distributed teams within the 24-Hour Knowledge Factory environment.

The goals of software development processes are to ensure high quality of the final service or product and to facilitate the communication between developers. Processes with rigid conventions, such as Tayloristic processes, are high-ceremony processes. In contrast, processes with few and flexible conventions are considered low-ceremony, agile, and more relevant for use in a distributed environment. However, low-ceremony processes such as the Personal Software Process (PSP) (Humphrey 1995) incorporate the conventional approach of individual ownership of development artifacts. As such, while PSP could not be directly applied to the 24-Hour Knowledge Factory environment, it still served as the inspiration for CPro. CPro incorporates new approaches that minimize the need for communication between collaborating groups, reduce the incidence of software defects, help to decide whether to decompose tasks, and how to assign subtasks between different collocated and distributed workers.

Historically, the decomposition of activities has served as the catalyst for new work models and new technologies. The IBM System 360 computer, for example, separated the mainframe hardware from the software logic, and enabled each set of employees to add value without knowledge of the work being performed by the other set of employees. If one uses computer terminology, this process of decomposition leads to a set of modules, where each module can be comprehended by one person; this person is the one who designs the module and bears responsibility for answering all questions related to it. Subtasks can sometimes be performed in complete isolation from sibling subtasks. More commonly, the business application is more complex. Each change in the task or subtask leads to a rippling wave of secondary changes in other subtasks. This introduces the requirement for lateral communication among collaborating sites.

In order to mitigate development risks introduced by communicating across culture, languages, and time zones and to provide 24-hour access to code owners, the concept of composite persona (CP) was formulated (Denny et. al. 2008). A CP is a highly cohesive micro-team that, like a corporation, possesses simultaneous properties of both an individual and a collection of individuals. A composite persona is designed to act as a singular entity, even though it comprises of (at least) three individuals, with one person at each site, with one site being active at any point in time. This configuration does not imply, however, that all sites possess the same number of persons; this is because one developer may belong to more than one CP. Using this notion of CPs, development proceeds in a manner similar to the traditional one; the sole difference is that the owner of each component is not an individual, but a CP. This CP is actively involved in the process of development and conflict resolution on a round-the-clock basis.

In the composite persona model, tasks are divided vertically, with teams working in a time-sequenced manner. Communication plays a major role in determining the success of the composite persona model. There are three different types of communication with the first being handoff. As the succeeding site turns on and a new driver takes responsibility for the CP, the handoff procedure is necessary. The handoff procedure used during the implementation of the concept development prototype system is derived from the one used in the Scrum agile process (Schwaber and Beedle 2002). In the latter case, Scrum stand-up meetings occur for co-located developers, first thing in the morning. All attendees briefly summarize what they accomplished the previous workday, what problems they encountered, and what they expect to accomplish during the day ahead. In our case, such debriefing takes place via CPro. In addition, CPro incorporates automated mechanisms to estimate delivery schedules, reduce defects, propagate knowledge within the CP, and heuristically assign workloads to members in a manner that will maximize overall productivity.

The second type of communication is lateral communication, which involves real-time synchronous communication between two active, co-located CPs. The third form of communication consists of lateral communication with handoff. The organization of CPs, as described above, is intended to provide the following benefits:

- **Smooth Transition:** The process of decomposition, design, and assigning ownership to individual subtasks is essentially the same whether development is done by individuals or squads.
- **Increased Trust:** Establishing trust is of pivotal importance with distributed teams. This process is greatly facilitated when all members of the team share common goals and trust each other. Since a CP is relatively small, typically with only 3 members, trust is easier to establish than in larger group settings.
- **Convergence:** As members of a CP work closely together, their knowledge will converge faster than with other approaches.
- **24-Hour Access to Responsible Person:** One knowledgeable person is available at all times.
- **Higher Truck Number:** Derived from the worst-case scenario where one or more project members get hit by a runaway truck, the truck number of a project is a useful metric for expressing the degree of vulnerability to the loss of critical talent.
- **Localizing Lateral Communication:** Lateral communication between distributed sites is very costly in terms of introducing time delays. Using the concept of CPs, lateral communication can be transformed into local communication.
- **Lower Number of Defects:** Because three (or more) persons are working on the same subtask in a sequential manner, each individual is able to act as an auditor for the work performed by his or her predecessor. This can reduce the number of defects, and also enable earlier detection of the defects.

MultiMind: MultiMind is a concept development prototype collaboration tool that incorporates the concepts of CPro and CP, in conjunction with several other advanced ideas proposed by other researchers. Its high-level architectural view is predicated on three fundamental principles: automate everything that can be automated; store everything that can be stored; and minimize the cognitive overhead for cooperation. To accomplish these directives, all operations on subtasks are recorded into a repository within MultiMind. Whenever any developer accesses some form of electronic memory, including a previous email message, the World Wide Web, or the project knowledge-base, such access is considered to be a Knowledge Event and is recorded within the repository.

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 and Gupta 2006, Mitra and Gupta 2008). When knowledge is spread over multiple

locations and time zones, the knowledge transfer activity becomes a critical aspect of the new IS methodology. UMEA is a tool for automatically organizing data objects into collections that are specific to tasks - this type of approach reduces the time to navigate through an information repository and makes it possible to locate task specific knowledge [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 search parameters for knowledge is of special importance.

The simplest manner in which knowledge transfer can take place between two developers is through a one-on-one conversation. This is not possible for the 24-Hr Knowledge Factory scenario due to time differences and other reasons; hence, proper code documentation becomes very important. Traditional approaches require the developer to possess a lucid writing ability, in order to create good documented code. More advanced solutions have been developed by the research group at the University of Arizona; one of them involves combining code documentation techniques with voice recognition capabilities [O'Toole 2008], and is called Echo Edit. EchoEdit allows programmers to choose between using text comments and voice messages. For example, text comments could be used for syntactical or low-level details, while voice messages could be used for addressing high-level ideas. EchoEdit supports three user actions: the recording of an audio comment, the playback of the audio file, and the conversion of the audio file into a text comment.

The prototype software is being evaluated by a team consisting of faculty and students in three countries: the Wroclaw University of Technology in Poland (WUT), the University of Arizona, Tucson, USA (UA) and the University of Technology, Sydney, Australia (UTS) (Chaczko, Klempous, Nikodem, & Rozenblit, 2006).

Case Study

Traditionally, face-to-face interaction was deemed necessary for transferring tacit knowledge between individuals and organizations (Porter 1998; Sternberg 1991; Tallman et al. 2004). Since physical distance was considered to impede inter-personal collaboration, most organizations opted to locate cross-functional teams at a single site (Eppinger and Chitkara 2006). Recently, researchers have observed that advances in information technology enable distributed teams to

work effectively without meeting face-to-face (Cummings 2004; Mazneski and Chudoba 2000; Espinosa et al 2007). Carmel (Carmel 2006) studied the limitations of executing work around the clock across multiple time zones at Infosys Ltd., a software firm based in India.

In this context, a one-year long detailed study at IBM deserves mention here. While it pertains to a two-site global work environment, the insights gained from this case study are helpful for understanding the dynamics of environments involving three or more sites.

All the members of collocated team were based at one site in the US. The other team was distributed between one site in the US and the other in India. Except for this difference, the two software development teams studied at IBM were virtually identical. Each team had seven core developers, of similarly varying experience and responsibility. Both teams were managed by the same development manager and the same project manager. The meetings of both teams ran in the same format and were also recorded in the same format, by the same individual. The products developed by the two teams were of similar complexity and each required the same skills and technology to build.

At the commencement of this study, it was felt that:

(i) The collocated team would demonstrate higher productivity, in terms of final outputs but without taking cost into consideration, because it would involve the overhead of transferring tasks back-and-forth on an incremental basis;
(ii) The distributed team would demonstrate lower costs because part of the staff is based in India and is paid lower salaries;
(iii) The distributed team would exhibit lower cost-benefit ratio if both productivity and costs are considered on a concurrent basis;
(iv) The distributed team would make greater use of automated collaboration technologies in order to overcome the inability for the two components of the distributed team to interact on a face-to-face basis; and
(v) The overall quality of the end-product would be roughly similar in the two cases.

Details of costs were not available because of corporate policy. Based on a careful review of earlier literature, the following set of 11 hypotheses was formulated.

H1: The distributed team will rely more heavily on written communication for group discussion.
H2: The distributed team will rely less (than the collocated team) on broadcast style email messages.
H3: The distributed team will conduct longer discussions primarily in written (email) form.
H4: The distributed team will send fewer logistical messages to members of the group.

H5: The distributed team will make major use of the source code modification process to resolve issues, in place of informal collaboration, before the 'feature freeze' date.
H6: The socio-technical system of the distributed team will be less interconnected (as compared to the collocated team).
H7: The distributed team will rely more on meetings for short term issues.
H8: The distributed team will formally assign tasks in meeting format.
H9: The output of the distributed team will be similar, in terms of quality, as that of the collocated team.
H10: The distributed team will rely more on formal systems for knowledge capture, as compared to the collocated team.
H11: The productivity of the distributed team will be lower than that of the collocated team (because of the overhead involved in transferring tasks back and forth on an incremental basis).

H1 through H4 describe written communication, which in this field study refer to electronic mail messages. H4 refers to logistical messages, which are defined as being related to a specific task or action to be completed in less than a week's time. H5 refers to a source code modification process. H5 also refers to a "feature freeze" date, a milestone used by both teams to complete programming tasks required for all features within the given software release. H6 refers to a socio-technical system, which in this case was tested by examining the discrete modules of source code being developed (as distinguished by the teams), and the number of modules of source code that had more than one individual contributing to them. H7 and H8 refer to meetings that were conducted over the phone or in person. H9 refers to quality and H11 refers to productivity; both of these parameters were assessed through qualitative interviews.

This longitudinal study of collocated and distributed software development teams at IBM is somewhat similar to the approach used by Majchrzak et al. (2000). The design is a "quasi-experiment" (Cook and Campbell 1979). Quantitative and qualitative data were systematically collected over a period of one full calendar year. Since the main project deliverable was on a one-year timeframe, every major point in the project lifecycle from its inception to the delivery of the end product. Data were collected using the following mechanisms:

- **Personal Interviews:** Hour-long personal interviews were conducted with each of the developers on each team.
- **Weekly Meetings over One Year, Coding System for Tasks and Status:** The weekly meetings of each team were analyzed to gain insights into the processes of formal task allocation and knowledge sharing, on a group-wide basis, for each team.
- **Software Problem Reports:** Each development team kept track of fixes requested or made to the code base via Software Problem Reports (SPRs). These SPRs contained information on the problem being reported, as well as the history of knowledge provided

by various developers in resolving the issue and information regarding the actual fix to the issue. A software tool was written to extract data from the SPR archive on the following issues: main developers overlapped with; average delay between developer inputs; ratio of collaborative to individual SPRs; and average time to resolution.

- **Source Code Control System:** Each of the two teams used a source control system to log the modifications made to each element of the source code for the team's product.
- **Group Email Exchanges:** A software tool was written to analyze electronic mail (e-mail) sent to all members of each team. A "thread" refers to the entire set of messages written in response to an initial electronic broadcast or request for information.

Table 3: Results from IBM Case Study

Hypothesis	Process Variable	Distributed Team		Collocated Team		T-test ($p<0.05$)
		Mean	Standard Deviation	Mean	Standard Deviation	
H1: The distributed team will rely more heavily on written communication for group discussion.	Contributors per email thread	1.73	1.55	1.50	0.74	Inconclusive
H2: The distributed team will rely less (than the collocated team) on broadcast style email messages.	Average weekly email threads	10.42	5.05	19.85	10.75	Confirmed
H3: The distributed team will conduct longer discussions primarily in written (email) form.	Average emails per thread	2.32	2.25	1.75	0.95	Inconclusive
H4: The distributed team will send fewer logistical messages to members of the group.	Average weekly emails	17.06	10.13	29.91	19.55	Confirmed
H5: The distributed team will make major use of the	Source code check-ins prior to	53.82	74.56	11.56	11.0	Confirmed

source code modification process to resolve issues, in place of informal collaboration, before the 'feature freeze' date.	deadline					
H6: The socio-technical system of the distributed team will be less interconnected (as compared to the collocated team).	Average number of developers per code element	1.10	0.2	1.63	1.04	Confirmed
H7: The distributed team will rely more on meetings for short term issues.	Fraction of tactical (vs. strategic) meeting items	0.81	0.17	0.39	0.22	Confirmed
H8: The distributed team will formally assign tasks in meeting format.	Percent of task assignment (versus status) meeting agenda items	0.35	0.13	0.24	0.17	Confirmed
H9: The output of the distributed team will be similar, in terms of quality, as that of the collocated team.	Average SPR actions per week	134.21	168.3	104.37	152.39	Inconclusive
H10: The distributed team will rely more on formal systems for knowledge capture, as compared to the collocated team.	Average # of individuals modifying SPR state	3.25	0.97	1.74	0.34	Confirmed
H11: The productivity of the distributed team will be lower than the collocated team	Average SPR time to resolution	113.80	83.17	120.72	130.45	Inconclusive

(because of the overhead involved in transferring tasks back and forth on an incremental basis.						

Table 1: Comparison of Outcomes for Key Process Variables

Of the 11 hypotheses, 7 were validated by the data from this case study. The statistical tests for the other four were inconclusive; these were H1; H3, H9, and H11. The last one is perhaps the most significant: we started with the premise that the productivity of the collocated team will be higher as it avoids the overhead involved in transferring tasks between team members on a frequent basis. This premise was not substantiated by the data based on standardized tests.

A detailed analysis of the data shows that both teams exhibited similar performance in terms of the quality and speed of their work (as measured by weekly SPR actions and average time to resolve SPR's, respectively). In terms of significant differences between the two teams, average number of individuals modifying the SPR state for a given SPR was significantly higher for the distributed team (3.25) than the corresponding figure for the collocated team (1.74). This highlights the fact that the SPR database was used by the distributed team as a mechanism for collaborative knowledge sharing. Overall, the geographically dispersed structure of the distributed team encouraged its members to have a higher degree of documented decisions, and thereby led to a much superior knowledge repository.

Overall, the case study at IBM showed that distributed teams are able to utilize emerging technologies in innovative ways and can actually outperform collocated teams. Similar evidence is now coming from other disciplines. For example, psychiatric consultations with individuals in prisons are progressing better via video links than on a face-to-face basis, and teletrauma surgeons have been able to increase survival rates for accident victims in rural areas.

Relevance of 24-Hour Knowledge Factory paradigm to IS and non-IS fields

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 use of the 24-Hour Knowledge Factory paradigm to enable these systems to be built quicker and cheaper.

The second involves the application of the 24-Hour Knowledge Factory paradigm to other knowledge-based activities ranging from medical services to logistics planning, and from financial analysis to product design. In 2005, one-third of the deadlines of Office Tiger Inc. were shorter than three hours, and about half of the deadlines relate to work that needed to be completed within a day [Wharton 2005]. The firm provided services for financial analyses, accounting, asset pricing research and corporate banking firms. Frequently, its clients completed 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 used a system called T- Tracks to track work in progress and to serve as 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. Pipal Research is another company that focuses primarily on agile and distributed execution of various accounting and financial tasks.

Note that while there are some similarities, the 24-Hour Knowledge Factory concept has significant differences from the concepts of offshoring and globally distributed teams as summarized in Table 4.

Table 4: Globally Distributed Teams and Offshore Outsourcing of Information Work versus the 24-Hour Knowledge Factory Paradigm: A Comparison

Factor	**Global Teams / Business Process Outsourcing**	**24-Hour Knowledge Factory Paradigm**
Division of Work	Non-overlapping subsystems are, integrated, post-production into a main system; or non-overlapping chunks of work that different entities (such as in-house operations department and external BPO firm) execute (such as in a BPO firm and in-house operations department Are subsequently integrated together.	Same body of work that is incremented and augmented by different functional units.
Mode of Processing	Parallel Processing	Sequential Processing
Work Completion Cycle and Frequency of Transfer between Units	Can range from under a week to over a year (in large application development projects).	Three times during a 24-hour period.
Relationship between Functional Entities	Contractual with buyer–client responsibilities delineated in advance, and augmented by Service Level Agreements.	Peer-to-Peer, with the different collaborating entities becoming extended organizational forms of each other.
Responsibility for Output Quality and Locus of Control	One party; usually, the sponsor organization, in US/Europe, is responsible for auditing the quality of output of other entities.	Each entity is equally responsible for the quality and audits the work of all other entities.
Governance	Contracts with metrics-based on service-level agreements with penalties (incentives) for under-performing (exceeding) these metrics.	Incentives based on achieving shared market-facing objectives and multi-point evaluation of performance; metrics based on service level agreements rarely used.
Knowledge	Formal codification of work;	Composite Personae: human

Transfer Mechanisms	electronic repositories of data that can be queried.	experts delivering knowledge and context through human intervention; interactive, real-time systems; and real-time interorganizational teams.
	Real-time interactions are infrequent and are exceptions to the normal operating mode.	Frequent, real-time human-intervention based interactions are the norm.
Capabilities of Functional Units	Mostly complementary.	Identical or near identical; each functional entity can provide services to other entities.

Owners of call centers were among the first to embrace the concept of the 24-Hour Knowledge Factory. In a call center, the work is structured in nature. Contrast this with the work performed by the heads of countries and the presidents of major companies. Can we visualize a situation where the President of the U.S. works during the daytime, on the east coast of the U.S., and there are pseudo-presidents in East Asia and East Europe that perform the same role during the other days of the clock? No. The best emerging opportunities for exploiting the 24-Hour Knowledge Factory concept lie in the intermediate arena of semi-structured work as shown in Figure 3. Instances of semi-structured work arise in virtually all types of professional endeavors that involve mental work. The list includes professional work from finance, accounting, and legal arenas. Further, the work does not have to be office-based.

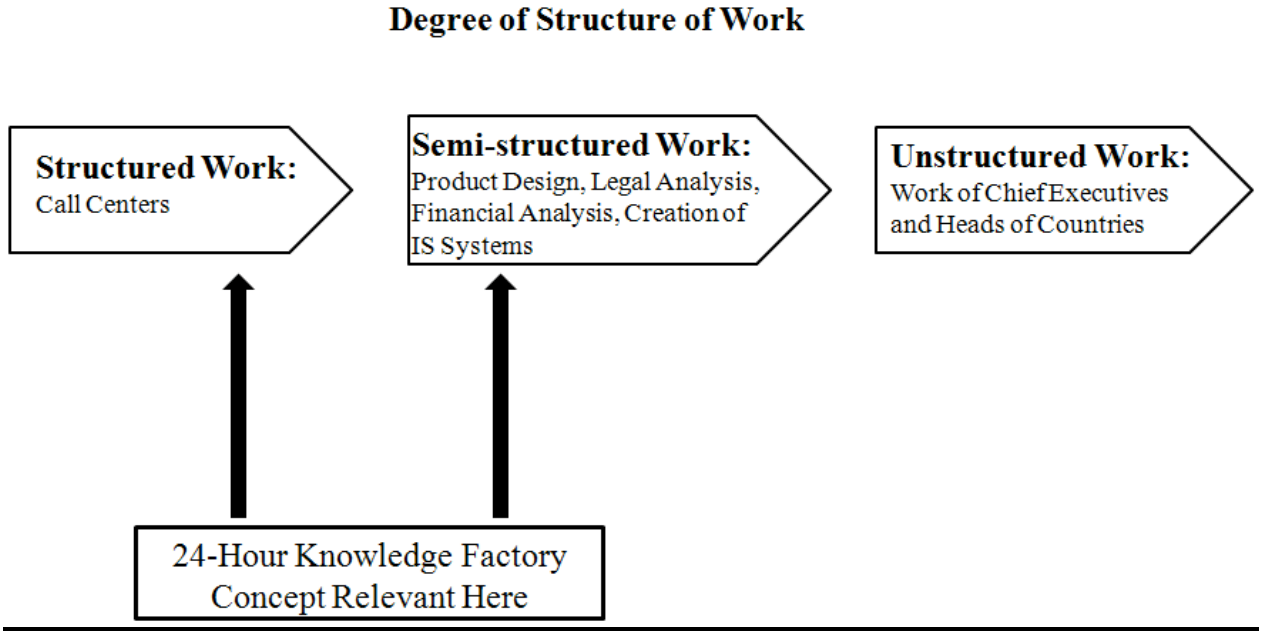

Figure 3: The notion of 24-Hour operations using 3 or more globally distributed centers will be incrementally deployed in applications of growing sophistication.

Each individual in the globally distributed work environment works the normal workday hours that pertain to his or her time zone, and then passes the task to a fellow worker located in a different time zone. An example of this phenomenon is seen in the automobile industry where

the concept of platform shifting allows members of a product development team in one country to work on a prototype and to transfer the work-in-progress to another country at the end of the workday [www.pbs.org/nbr/site/onair/transcripts/070209b].

The digitalization of work offers the chance for "strategic renewal" of certain firms and industries (Agarwal & Helfat, 2009). The travel agency industry is an example of an industry that could benefit from the digitalization, and subsequent virtualization, of work. Many travelers need 24-hour assistance that a traditional 9 to 5 travel agent is not equipped to provide; this is one of the reasons why travel agencies are going out of business. Now consider a situation where the US travel agency establishes strategic alliances with travel agencies in Australia and Poland. At any time of day and from any point in the world, a traveler is able to talk face-to-face with a travel agent using a computer or television-based system for interactive dialog. The adoption of such digitized and innovative mechanisms will enable the travel agencies to renew themselves and to compete with the airlines that took the initial lead by establishing travel support call centers in multiple time zones, all capable of accessing the digitized itinerary of the traveler.

Legal and Accounting Issues and Applications

Historically, when a significant difference in wages occurred, persons from the labor surplus areas would move to the labor deficient areas to bridge the gap in wages. This phenomenon of labor arbitrage has been gradually compromised by immigration barriers that countries have erected over the last couple of centuries. Offshoring involves the utilization of services of persons in foreign countries by surmounting immigration barriers through the application of contemporary information technologies. Offshoring will continue as long as desired talent is available in foreign countries and significant difference exists in skill levels and wages.

Many of the state governments in the US have adopted, or have seriously considered, legislation to discourage, or even prohibit, offshoring. Several researchers have recently analyzed the validity of the prohibitions and restrictions imposed by these state governments on government contracts and private entities. This analysis was motivated, in part, by the decision of the US Supreme Court to invalidate a specific Massachusetts law. The legislature of Massachusetts had earlier decided that since the country of Myanmar was deficient in terms of respecting human rights, companies doing business with Myanmar would be prohibited from doing business in Massachusetts. While leaving many rights with the states, the US constitution specifies that the US federal government holds exclusive rights on matters involving interstate commerce and foreign affairs. Based on these considerations, the US Supreme Court invalidated the particular Massachusetts law (Crosby 2000). Extending the same logic, the different pieces of anti-offshoring legislation approved by various state governments are in violation of the spirit of US

federalism and the US constitution, and are likely to be invalidated if and when they are taken up for judicial review (Gupta and Sao 2009)

From the viewpoint of the US Constitution, the federal government possesses the authority to impose laws prohibiting or restricting offshoring. However, the approval of such laws by the federal government will potentially be in violation of the commitments that the US has made to the World Trade Organization (Gupta, Gantz, Sreecharana, and Kreyling 2008). The US is a major proponent of free trade; this is a two-edged weapon because it gives countries access to foreign markets but simultaneously requires countries to open up their own markets too.

After the US constitution was adopted, there were multiple cases in which states wanted to aggressively promote resident companies by prohibiting out-of-state companies to conduct similar business in the particular state. For example, in 1798, the state of New York granted one company exclusive rights to ferry passengers to and from cities in New Jersey; this company had made major innovations with respect to steam boats. In 1812, New Jersey fought back and passed retaliatory legislation. Subsequently, the US Supreme Court intervened to allow Vanderbilt to come into direct competition from New Jersey. Many researchers have commented that this competition led to major innovations in the steamboat industry including drastic reductions in the price paid by passengers. Though the company that pioneered steamboats went bankrupt, other companies prospered and so did society as a whole.

We face a similar situation today. Two hundred years ago, the thorny issue was intra-state interests versus national interests. Now the crucial issue is national versus global. The state of Arizona is among the set of states that prohibit offshoring of IT work on government awards. Consequently, the tiny fraction of work that was earlier performed abroad was transferred back to the US and reassigned to be performed in other states within the US, even though the costs were much higher. Gradually, organizations will opt to get the work done in multiple places using a portfolio approach that enables 24-Hour delivery of services at the least cost; this applies both to private and public sectors.

With every job that is performed wholly or partially abroad, some transfer of intellectual property takes place, with long-term ramifications on the balance of intellectual property (IP) generation and consumption. In the US and in several other countries, the value of software and certain other types of intangibles is based on the income that these intangibles are expected to generate in the future. Significant transfers of intangibles occur in many service-based offshoring arrangements, and companies adopt different organizational models to conduct their foreign operations, based on taxation and other considerations. The scenario involving Controlled Foreign Corporations is analyzed by Wiederhold et al, 2009. The aspect of valuation of software and similar types of intellectual property in an offshore scenario is examined by Wiederhold et al, 2010. As these two papers highlight, such analysis still needs to be extended to cover the

notions of the 24-Hour Knowledge Factory and other work models that involve geographically dispersed teams.

Accounting companies are now utilizing remote resources to conduct certain accounting and audit tasks. So far, parts of the overall project are assigned to remote units. The same situation occurred with the computer industry, where the transition in work structure initially commenced with specific modules of the software being developed offshore; gradually, the concept of sequential and cyclic work is being embraced by leading computer companies. The same phenomenon is likely to occur in the accounting and legal arenas. Borsand and Gupta (2009) argue that small and sole practitioners stand to greatly benefit from such offshoring arrangements as they provide access to good legal services and experts at a fraction of the cost; this levels the playing field between clients with huge funds to spend on litigation versus clients with meager resources. The scope of legal process outsourcing (LPO) already includes liability limiting agreements, ERISA compliance, and certification and oversight models. Outsourcing in non-traditional areas, such as the public sector and the judiciary, involve additional considerations (Borsand and Gupta 2009).

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The legal sector and the health sector are two sectors that are heavily governed by laws and procedures at the state level in the US (Gupta, Goyal, Joiner, and Saini 2008). While the US Constitution specifies that the federal government has sole rights on issues related to foreign trade, the current environment is heavily constrained by regulations of non-federal bodies. Further, mechanisms for resolving problems involving offshoring of services need to be streamlined. One mechanism to achieve this objective is to create a new transnational layer along the lines that the European Economic Union has pursued for certain type of issues. This notion has been extended for global services in (Gupta, 2008). Addressing such issues will need effort, both at corporate and governmental levels.

Conclusion

The 24-Hour Knowledge Factory concept involves a successive, sequential, and circular work arrangement. Each center retains ownership of the endeavor for an 8-hour period, exclusively during daytime, in every 24-hour cycle. The distributed team can do identical tasks or complementary tasks. The ability to apply this paradigm to many other industries outside of the software industry exists, as many daily functions in multiple industries – accounting, consulting, and law, to name a few – employ a development cycle that is inherently dependent on sequential performance of specific functions. Studies show that distributed teams can now outperform collocated teams. This new work model will be increasingly deployed in accounting, legal, and other types of semi-structured professional endeavors.

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