Information Engineering Approach for Decision-Making in Textiles[1]

Yatin Karpe, George Hodge, Neil Cahill* & William Oxenham
North Carolina State University, NC
*Institute of Textile Technology, VA

Abstract: Information Engineering is defined as a technique for extracting the "meaning" contained in information to allow the understanding needed by a user to make a "right" decision. This paper mainly describes and discusses the concepts underlying the Information Engineering approach, viz. Knowledge Management and Information Quality, and emphasizes their role and application as they relate to the Decision-Making process. The importance and concept of modeling will also be discussed, specifically with respect to one type of universally accepted form of modeling called IDEF (Integrated Definition Language). A case study using IDEF (IDEF0 and IDEF1x) for knit machine operation is presented in brief. Research is in progress to develop an Information Engineering methodology for mapping (using IDEF principles) and simplifying the decision-making process for a particular decision in textiles, resulting in more effective and efficient decision-making by the textile personnel.

1. INTRODUCTION

The information systems developed over the last 30 years have been heavily technology based, while decision-making remained a human thinking process. It can be envisioned that the information system was a sort of a pipeline through which information would flow past various users in the organization. As particular users desired/needed some information to make decisions, they "tapped" the pipeline. This basic approach of people tapping the information flow as needed to make decisions is basically the same today. Unfortunately, as businesses became more complex and the system could generate increasing quantities of information, then the discriminating power of the user to select and digest the "right" information was stretched to the limit. This phenomenon, also known as information overload, resulted in inferior or downgraded decision-making, due to the sheer volume of information that had to be processed in a given decision-making time frame. As this dilemma

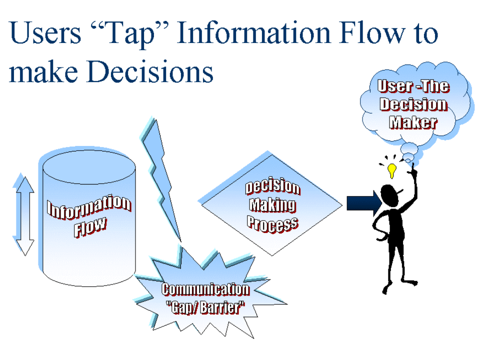


Figure 1: A Typical Communication System

of the information system and the human user increased, it evidently developed into a communication gap. Information systems primarily involve generating and distributing information throughout an organization. Such information transmission is the necessary first step in developing any communications capability. But information has no use, and therefore no value, until a decision-maker utilizes it. It is the human decision-maker who constitutes the

[1] Part of this paper was presented at the Textile Institute World Conference, Australia, 2001

second component of a communications system. The point of integration, where the human decision-maker "taps" into the information system is what forms the interface, and the design of this interface will influence the proficiency of converting information into decisions.

The ability of the decision-maker to make "right" decisions does not depend on information itself, but on the meaning and understanding derived from that information. If information access is a key driver, providing the right information filtering capabilities emerges as a major challenge. It is here that Information Engineering plays a vital role. Based on the above discussion and research conducted, the data-to-decision cycle model (The Decision Cycle) was developed to better understand the decision cycle and the Information Engineering approach. The conversion process by which raw data is translated into decisions of high quality is the Data-to-Decision cycle model. A parallel can be drawn between the components of the model and the present Information technology advancements. This process would assist in further diversifying the research so as to explore new and unique areas that would encompass the entire depth of the model. Different industry segments of the textile supply chain are being studied for the different Information Engineering stages.

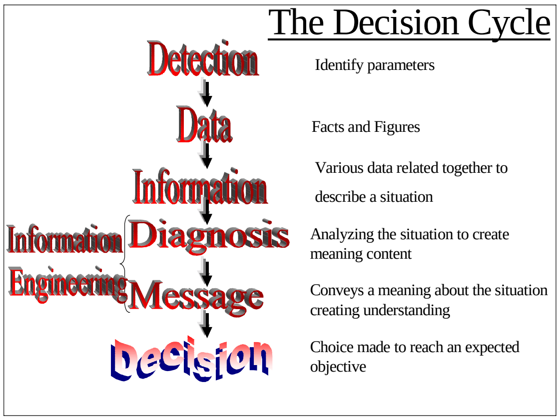


Figure 2: The Data-to-Decision Cycle Model

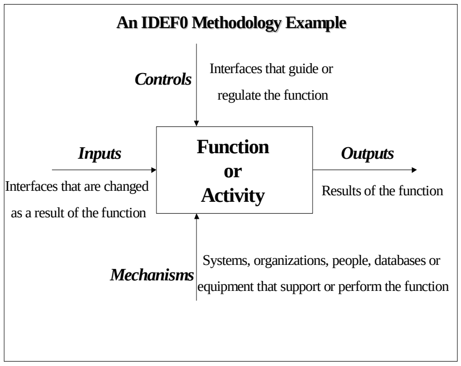
2. PRE-INFORMATION ENGINEERING STAGE

The "Detection" and "Data" parts of the model represent a data warehouse, which is a repository of the company's historical data. In regards to these stages, studies are being conducted on the profiling, classification and standardization of the data. Attempts were made to describe and define the data elements of specific relevance to decision-makers, such as superintendent, foreman, operator, maintenance personnel, etc., in knitting mills, one of the components of the textile supply chain, which in turn will assist in better understanding the decision-making process. Modeling (IDEF Modeling in particular) is used for this purpose. Results obtained will be utilized in mapping out a particular decision-making process in the weaving industry of the textile supply chain.

2.1 IDEF MODELING

IDEF stands for Integrated DEFinition language. It is a methodology for describing, managing and improving complex processes and systems. IT provides a common, public-domain language for modeling and describing processes, data, requirements, as well as functions (Cete, 2001). It was first developed as part of the US Air Force ICAM (Integrated Computer Aided Manufacturing) Program in the early 1980s (ICAM, 1981). Since then, it has become the most well known and widely used method worldwide for modeling because of its simplicity. Originally, IDEF method comprised of three non-integrated modeling techniques, namely - IDEF0 (for functional modeling), IDEF1x (for data and information modeling) and IDEF2 for dynamic modeling (Vernadat, 1996). IDEF0 added features to the SADT methodology, which made it a standard for use as the language to describe decisions, actions and activities that make up today's complex organizational environments (Wizdom Software, 1998).

2.2 IDEF0 PROCESS MODELING



An illustration of a basic IDEF0 model is shown in the figure. IDEF0 is a method designed to model decisions, actions and activities of an organization or system. IDEF0 models help to organize the analysis of a system and to promote good communication between the analyst and the customer. As a communication tool, IDEF0 enhances domain expert involvement and consensus decision-making through simplified graphical devices (Cete, 2001). As an analysis tool, it assists the modeler in identifying what functions are performed, what is needed to perform those functions, what the current system does right and wrong. Thus, IDEF0 models are often created as one of the first tasks of a system development effort. The text in the box is the name of the activity for which it stands, typically a verb or verb phrase. Each side of an activity box has a specific meaning. The left side is reserved for inputs, the topside is reserved for controls, the right side is reserved for outputs, and the bottom side is reserved for mechanisms (resources). This reflects system principles; Inputs are transformed to outputs; Controls constrain or dictate under which conditions transformations occur; and, Mechanisms describe the resources needed to accomplish a function. A top-down diagramming method such as IDEF0 goes from the general to the specific, from a single diagram that represents an entire system to more detailed diagrams that explain how the subsections of the system work. The IDEF0 Methodology is primarily used for understanding the *AS-IS* (Present State) environment - the functions that are carried out, the relationships between them, and the logical breakdown of those functions into their sub-functions. The *AS-IS* scenario is then utilized to design and develop the *TO-BE* (Future Proposed State) environment, thus allowing for process or function or decision improvement.

2.3 KNITTING PROCESS MODEL

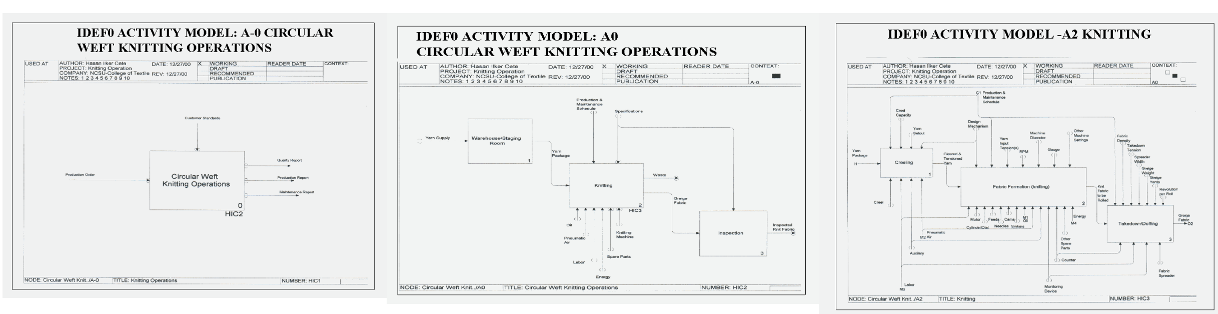


Figure 4: IDEF0 Knitting Models

A case study of IDEF0 modeling is shown in the three figures above (Cete, 2001). The base model is the A-0, followed by its decomposed diagrams. A-0 diagram (top) can also be called as the context of the function. When one clicks on the "circular weft knitting operations" activity box, the box pops up into another page that shows the presented A0 diagram (middle). A0 diagram can go one level down from "knitting" activity box. The lower-level diagram is named as A2 (bottom) because the operation selected in A0 diagram is second one, "knitting". The number seen on the lower right corner in "knitting" activity process box on A0 diagram formulates the lower level diagram node. Knitting represents the large diameter circular weft knitting machines' operations.

2.4 IDEF1x DATA/INFORMATION MODELING

IDEF0 describes the activities needed to perform functions. IDEF1x describes the information or data needed to perform the same functions, both automated and nominal (Cete, 2001). It is important to model information. In order to avoid business problems, information needs to be accurate, timely, in the right place and in the right format. When the model is made, it is important to define all the information that is needed to meet the mission and goal of the organization. The IDEF1x standard defines what is to be known to do what is to be done. It is easy to communicate with others through standard syntax and representations by using IDEF1x. IDEF1x is based on the primitive form of the entity-relationship model as shown in the adjoining figure. Each information object is modeled as an entity (represented by a named rectangle and defined by its list of attributes, which can be listed in the box). Entities can be connected by named lines representing the relationships. Relationships can be of type 1:1. 1:n, or m:n, as shown in the figure 5.

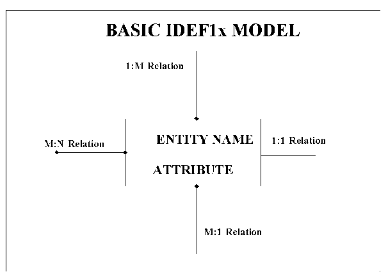


Figure 5: Basic IDEF1x Model

2.5 KNITTING DATA MODEL

As part of the ongoing research in IDEF Modeling, and as a continuum to the IDEF0 modeling examples developed, a data/information model was developed for large diameter circular weft knitting as shown in the adjoining figure (Cete, 2001). A data model defines the entities and their attributes along with the relationship among the entities. A specific relationship is always involved with two entities. In this data model there are 12 entities defined. They are production order, style card, yarn package, creel, knitting machine, takedown/doffing unit, monitoring device, greige fabric, maintenance report, quality report, production report and knit operator. All these entities involve knitting machine operation. The activity models and the data model were prepared by using WizdomWorks98 Office software; ProcessWorks and DataWorks.

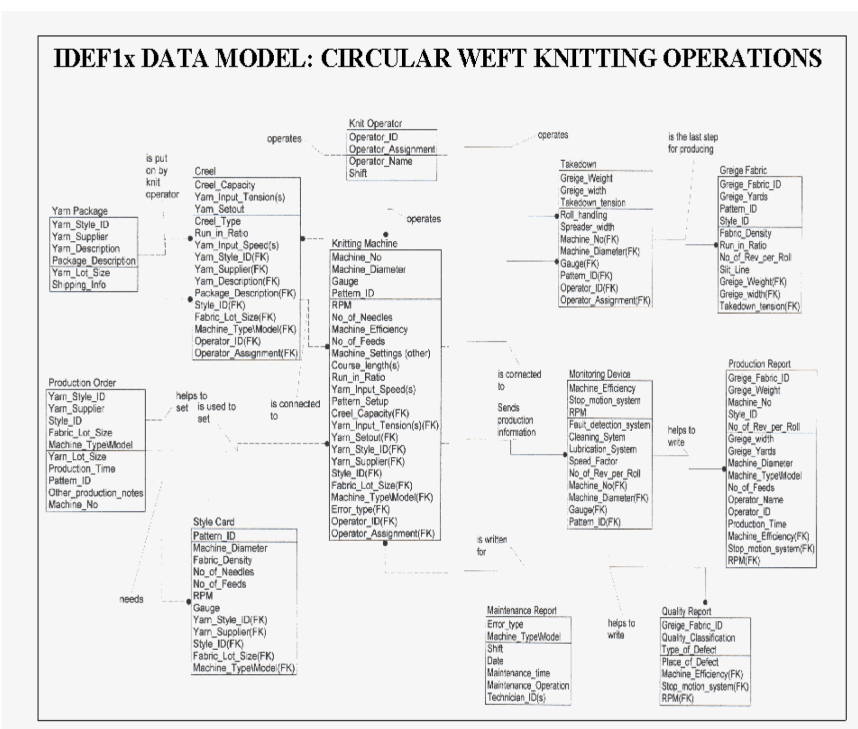


Figure 6:IDEF1x Knitting Data Model

(Results of this research (IDEF process and data models) will be discussed in detail during the presentation). These process and data models will further assist in defining the concepts of the decision-making process in knitting or similarly in any other sector of the textile supply chain. Thus, IDEF can be used as a tool to model the decisions and assist in developing an Information Engineering methodology. But before that is done, research is in progress to define and understand the various concepts (such as Knowledge Management and Information Quality) underlying the Information Engineering approach as being used in this specific research context.

3. INFORMATION ENGINEERING

While the data being generated and information processed is at one end, the outcome of the decision being made is on the other end. But if we look at the center of the cycle, we realize that right decisions are not made merely by obtaining information, but by the correct diagnosis of the meaning of that information. If we interpret the meaning correctly, then we get the right message, which means we will probably make the right decision. It is here, in the center of the Decision cycle that machine intelligence can be created and it is here that Information Engineering can be applied to the manufacturing system. Information Engineering can thus be used to bridge the gap between the Data to Decision phases. It is the right decision that leads to favorable outcomes for that company and this is where information actually creates value.

Information Engineering is defined as a technique for extracting the "meaning" contained in information to allow the understanding needed by a user to make a "right" decision. According to one of the authors (Neil Cahill) "When one has to make a decision, it is the meaning contained in the information that is needed to make a "right" decision, and not the information alone. Of all the information available in existing plant reports today, only about 10-15% of the information contained in these reports is actually utilized. This low information utilization occurs due to the desired information (vital information) being buried in the report and requiring more diagnostic time than the user can provide" (Cahill, 1997). It must be realized that 80% plus of the time to reach a decision is used simply to find the right information. According to Myers, "While all communication contains information, not all information has communication value" (Cahill, 1985). Therefore, the goal should be to optimize the quality of the messages transmitted through the interface from the information system to human user. Information Engineering assists in this process. The ability of the user to make “right” decisions does not depend on information itself, but on the “meaning and understanding” derived from that information. The sender attempts to convey meaning through the message of the information. It is the message contained in the information that transfers meaning. This suggests that one way to improve the value of information is the designing of a message interface. This interface enhances the meaning of information in order for the user to better understand the business situation in which he/she must make a decision. Information is the raw material of the human thinking. But it is the “meaning and understanding” that is the raw material of decision thinking. Information by itself has no meaning or understanding. The human decision-maker acquires meaning and understanding not from the raw information, but rather from the “message content” of that information. This conversion process by which raw data is translated into decisions is the Data-to-Decision cycle model (Karpe, 2000). And it is in the center of this decision cycle that Information Engineering plays a vital role.

Information Engineering is a technique for identifying appropriate information for specific sets of decisions, and then tailoring and relaying this information to support effective management decisions. Therefore, by designing information in such a way that it's fit for use - making what we can call "actionable information" in today's fast-paced, information overloaded environment - one can construct meaning out of the clutter of disjointed data fragments. This means that when information is converted into a meaningful format, it leads to knowledge of that particular situation, resulting in effective and efficient decision-making. Information Engineering could prove to be a tool in knowledge mobilization, one of the twenty-four "Critical Business Practices" identified for the creation of an agile enterprise (Dove & Hartman, 1998). Hence one approach of understanding the model would be to study and analyze the knowledge management process, which draws a close resemblance to the decision cycle model.

4. KNOWLEDGE MANAGEMENT

Knowledge Management (KM) can be compared to the Industrial Revolution, where the work shifted from hand-centric labor to machine-centric processes leading to an explosive rise in production and new technologies. In the same way, KM drives the shift from the manual generation of information (paperwork, which is still common today) to complete electronic processing (with the ability to effectively use and apply information). This Knowledge management revolution leads to faster rates of producing knowledge assets, and new technologies for adapting knowledge faster (Leibmann, 2000). A recent study by the Cambridge Information Network found that 85% of chief information officers surveyed believe that managing knowledge creates a competitive advantage by fostering better decision-making (Taft, 2000). The primary goal of knowledge management is to deliver the intellectual capital of the firm to the knowledge workers who make day-to-day decisions that in aggregate determine the success or failure of a business (Microsoft(a), 2000). Developing such capabilities is what this research is all about. But before we try to develop a tool to implement KM practices, it will be useful for us to lay some groundwork on the fundamentals of knowledge management.

4.1 DEFINITIONS: KNOWLEDGE AND KNOWLEDGE MANAGEMENT

Defining knowledge is an essential first step when investigating knowledge management. Knowledge can be defined in several different ways (Beckman, 1997; Van der Spek, 1997), one of them being information that has been organized, analyzed and reasoned to make it understandable and applicable to actively enable performance, problem-solving and decision-making (Turban, 1992). Knowledge is composed of two main types, focal and tacit: focal being knowledge about the object or phenomenon in focus (or of explicit interest) and tacit is knowledge that is used as a tool to manage or improve what is in focus. For example, if a certain piece of information represents focal knowledge (say end-breaks in ring spinning), how a person perceives that information and operates on it is driven by his tacit knowledge (decision to continue or stop that machine, examine the physical attributes of the spindle or yarn, and so on).

Knowledge Management also has been defined in several different ways by different authors (Petrash, 1996; Wiig, 1997; O'Dell, 1996). One definition being the practice of identifying, capturing, organizing and processing information to create knowledge, which is then distributed and otherwise made available for others to use and to create more knowledge (Radding, 1998), which in turn creates more value, and it is precisely this value-enhancement in decision-making that is needed to be achieved with the Information Engineering approach.

4.2 KNOWLEDGE PROCESS, FUNCTIONS AND PHASES

The very process that is used to create, communicate and apply knowledge results in new knowledge. New knowledge almost always begins with an individual. A brilliant researcher has an insight that leads into a new patent. A shop-floor worker draws on years of experience to come up with a new process innovation. In each case, an individual's personal knowledge is transformed into organizational knowledge, valuable to the company as a whole. The result is a knowledge cycle in which data is transformed into information. The information is then culled and enhanced and transformed into knowledge. The knowledge is then applied and the results are documented, creating new data and information and recommencing the process. And this in essence is the aim of this project. Once the knowledge is engineered for specific end-use and assists in decision-making for a particular decision, it could be made available for not only enhancing the efficiency and effectiveness of that decision, but also used as a basis for other decisions across various other functions and departments.

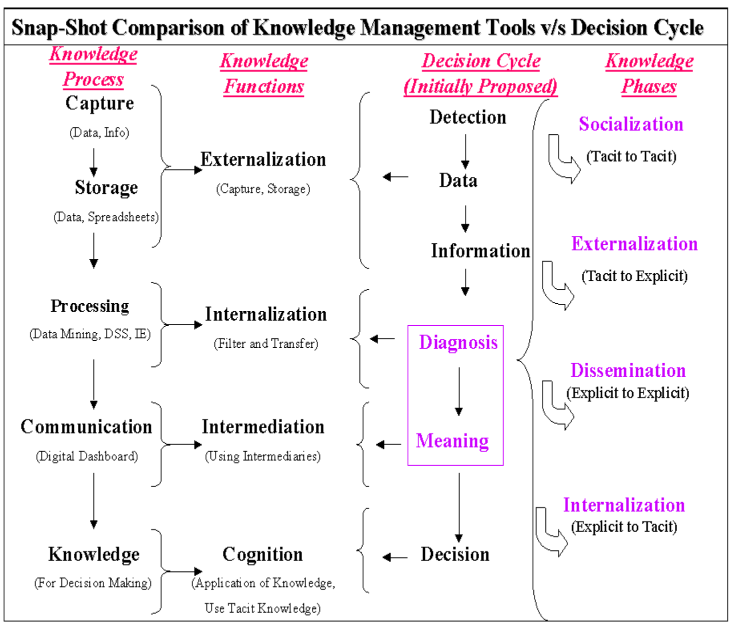


Figure 7: Knowledge Management Tools v/s Decision Cycle

The following figure is a summarized version of understanding the relation of the various components of knowledge management versus the decision model and the possible approach that could be used for the purpose. The knowledge process (Radding, 1998) and the knowledge functions (Frappaolo, 1998) are self-explanatory and draw a close resemblance to the knowledge cycle explained above and the Decision cycle model (Karpe, 2000). Related to this knowledge process and functions are the four basic knowledge phases (Radding, 1998; Malhotra, 2000):

Socialization (Tacit -to- Tacit) - The conversion from tacit knowledge to tacit knowledge through sharing of experiences, imitation and practices. This type of activity occurs during coaching, in apprenticeships, at conferences and seminars or simply during employee interaction during recesses.

Externalization/Articulation (Tacit -to- Explicit) - Also referred to as capture. The conversion from tacit knowledge to explicit knowledge, usually by articulating the tacit knowledge and turning it into explicit form, such as a report or document.

Dissemination/Combination Phase (Explicit -to- Explicit) - The conversion from explicit knowledge to explicit knowledge by the owner's sharing it with one another. Dissemination is the primary way knowledge is leveraged throughout the organization.

Internalization (Explicit -to- Tacit) - The conversion from explicit knowledge back to tacit knowledge, enabling workers to incorporate the knowledge into the way they respond and behave when faced with a situation or problem, to which the knowledge applies.

This spiral of knowledge elicits one fact; knowledge creation results form efficient and effective use of the existing information. And in order for the user or decision-maker to utilize this information effectively, the quality of that information is of prime importance. Enhancing the quality of information results in better understanding of the situation, resulting in effective decision-making.

5. INFORMATION QUALITY

Information quality problems hamper virtually every area of a business, from the mailroom to the executive office. Every hour the business spends hunting for missing data, correcting inaccurate data, working around data problems, scrambling to assemble information across disintegrated databases, resolving data-related customer complaints, and so on, is an hour of cost only, passed on in higher prices to the customer. That hour is not available for value-adding work. Senior executives at one large mail order company personally spend the equivalent of one full-time employee (senior executive) in reconciling conflicting departmental reports before submitting them to the Chief Executive Officer. This means that the equivalent of one senior executive's time is spent or wasted because of redundant and inconsistent (nonquality) data. According to Bill Inmon, 80 to 90 percent of the human efforts in building a data warehouse are expanded in handling the interface between operational and data warehouse environments (Inmon, 1992). The bottom line is that information quality problems hurt the bottom line. The social and economic impact of poor-quality data costs billions of dollars (Wang, 1995; Strong et al, 1997). Quality experts agree that the costs of nonquality are significant. Quality consultant Phil Crosby, author of Quality is Free, identifies the cost of non-quality to manufacturing as 15-20 percent of revenue (Crosby, 1979). J.M. Juran pegs the cost of poor information quality at 20 to 40 percent of sales (Juran, 1988), Kearny puts this cost at 25 to 30 percent of sales dollars, while in service companies, poor quality can amount to an increase of 40 percent in operating costs (Boyle, 1992). Furthermore, as much as 40 to 50 percent or more of the typical IT budget may actually be spent in "information scrap and rework", a concept well known in manufacturing. Following the analogy between manufacturing and information systems, we can clearly see that there is a significant economic benefit to be gained if data or information quality can be managed effectively (Wang, 1992). Information quality is a business issue and information quality improvement is a business necessity. For organizations in a competitive environment, information quality is a matter of survival, and then of competitive advantage. For organizations in a public and not-for-profit sectors, information quality is a matter of survival, and then of stewardship, of stakeholder resources.

5.1 INFORMATION QUALITY: DEFINITION -

Information Quality is defined as "consistently meeting the knowledge-workers and end-customers expectation", through information and information services (English, 1996), enabling them to perform their jobs efficiently and effectively. Information quality describes "the attributes of the information that result in user (customer) satisfaction (Nayar, 1996). There are two significant attributes or definitions of Information Quality. One is inherent and the other is pragmatic information quality (English, 1999).

Inherent Information Quality is the correctness or accuracy of the data. If all facts that an organization needs to know about an entity are accurate, that data has inherent quality - it is an electronic representation of reality.

Pragmatic Information Quality is the degree of usefulness and value data has to support the enterprise processes that enable accomplishing enterprise objectives. In essence, pragmatic information quality is the degree of customer satisfaction derived by the knowledge workers who use it to do their jobs.

Information can be represented by the formula (English, 1999):

Information = f(Data+ Definition + Presentation)

The three components that make up the finished product of information are separate and distinct components that must each have quality to have information quality. If we do not know the meaning (definition) of a fact (data), any value will be meaningless and we have non-quality. If we know the meaning (definition) of a fact, but the value (data) is incorrect, we have non-quality. If we have a correct value (data) for a known (defined) fact, but its presentation (whether in the form of a written report, on a computer screen, or in a computer-generated report) lacks quality, the knowledge worker may misinterpret the data, and again we have non-quality. Thus information quality is not an esoteric notion; it directly affects the effectiveness and efficiency of business processes.

5.2 DIMENSIONS OF INFORMATION QUALITY -

Studying the 5-dimensional model creates another form of representing the information quality phenomenon (Albrecht, 1999). As seen in the figure below, the Data logistics and data protection parts are concerned with the capture and storage of the data. The Information behavior encompasses what human beings do with the data and information, viz. recording information manually or by computer, paraphrasing, getting information from others, etc.

Information design is at the heart, using software and other tools to create new information and knowledge by transforming source information into meaningful form. This meaning is then used for knowledge creation, wherein the human skill of drawing insights and conclusions from the existing information comes into play. It could also lead to new inventions, conceptualizing new ideas, conceiving new strategies and building new models and rethinking existing beliefs. Thus, the five dimensions further strengthen the Knowledge Process/creation and the Knowledge phases concepts that were discussed earlier and will provide us with a strong foundation to design a new approach.

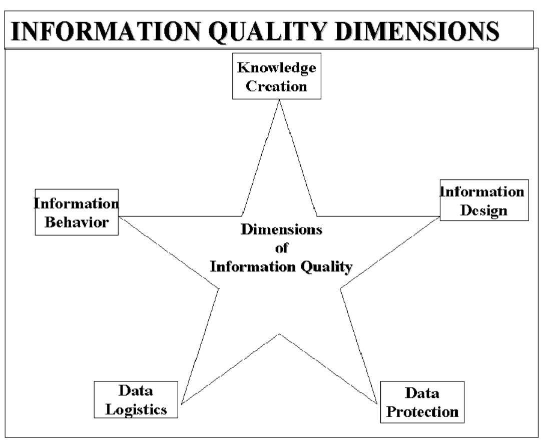


Figure 8: Information Quality Dimensions

In addition to these concepts, literature has also been reviewed in the areas of cognition (memory, inferences, etc.) and problem solving and reasoning (heuristics, biases, etc.). All this literature reviewed will be utilized to design and develop an effective research approach towards meeting the main objective of this research.

6. RESEARCH APPROACH -

Based on the literature reviewed in different areas**,** information will be gathered using a case study approach, focused on the current decision-making process of textile companies. Case study research is a widely used and accepted approach in the development of modern management theories and models, since it enables development of new ways of describing reality using qualitative information. Furthermore, it provides reasonably good potential for result generalization from very few cases, or even a single case, based on the opportunity for holistic view of a phenomenon or series of events. The industry sample will include manufacturing sites from one segment of the textile supply chain complex, viz. weave room (weaving). Thus, the unit of research analysis will be a textile (weaving) manufacturing plant, and not the entire textile industry. The main study will focus only on approximately 3 to 5 textile plants for its study. In order to obtain information for studying and analyzing the present decision-making process, concepts and ideas learned from the literature reviewed and the knitting industry study will be utilized and interpreted to formulate a structured interview. Concepts, such as problem solving heuristic, the knowledge phases (Socialization, Externalization, Dissemination, Internalization) and cognition (different biases) will be used to define the “As-Is” scenario and possibly propose a structured “To-Be” approach for effective and efficient decision-making with regards to the weave room efficiency decision. Initially, a pilot study will be undertaken in order to evaluate the functionality and the result generation capability of the interview. This process will assist in restructuring or refining the interview process for more effective and efficient response generation. Efforts will be made to collect and analyze plant reports, forms and such other documents that are deemed fit for information collection and analyzing situations. The information obtained will be graphically represented using the Wizdom software for process modeling (IDEF0) and data modeling (IDEF1X) methodology. This process will also assist in identifying and isolating the inherent deficiencies in the present decision-making process and standardize a potentially simple map of a decision-making process for the weave room efficiency decision, which could later be utilized across the entire textile chain for different other decisions in different parts of the textile chain.

7. SUMMARY -

The goal of the current research is to fundamentally enhance the decision-effectiveness of the textile personnel on the plant floor, using the data-to-decision cycle model as the basis. Since this research is in progress and has several angles to it, this paper specifically deals only with the research foundation and the concepts underlying the approach that will be adopted. Results of the approach adopted will be ready for presentation at the next years’ conference. The Information Engineering approach could prove to be a valuable asset in improving data and information quality with the use of knowledge management and modeling tools. Thereby reducing the overload (information overload) that tends to occur in the present generation highly automated machinery and making it simpler for the personnel on the plant floor to make the right decision. In combination with Knowledge Management and Information Quality, Information Engineering can eventually lead to the development and creation of a kind of Digital Decision Dashboard (D^3), which would be the decision-making tool of the next generation for the textile industry. A digital dashboard is defined as a customized solution for the knowledge workers that consolidates personal, team, corporate and external information and provides a single click access to analytical, and collaborative tools (Microsoft, 2000). It brings an integrated view of a company's diverse sources of knowledge to an individual's desktop, enabling better decision-making by providing immediate access to key business information. The D^3 can be a similar tool for decision-making in textiles, capturing and disseminating vital management information for effective and efficient decision-making, thus addressing a critical need presently facing the textile industry.

ACKNOWLEDGEMENTS

The authors would like to thank the National Textile Center (NTC) for providing the required support for this research.

REFERENCES

1. Albrecht, K. "Information, the next quality revolution?", Quality Digest, June 1999.
2. Beckman, T. "A Methodology for Knowledge management", IASTED- AI and Soft Computing Conference, Banff, Canada, 1997.
3. Beckman, T. "The Current State of Knowledge Management", The Knowledge Management Handbook, Jay Liebowitz, ed., CRC Press, 1999
4. Boyle, S. "Quality, Speed, Customer Involvement and the New Look of Organizations" seminar, Excel, pg.17, 1992.
5. Cahill, N. "Analyzing textile plants of the 21st. Century", ISA - textile division, June 1997.
6. Cahill, N. "*Information Engineering* – Measuring use value of information", ITT Report, 1985.
7. Cete, H. "Information Technology and Data Modeling in Large Diameter Circular Weft Knitting with Data Standardization and Profiling", M.S. Thesis, North Carolina State University, Raleigh, NC, 2001.
8. Crosby, P. Quality is Free, Penguin Group, New York, 1979.
9. Dove, R & Hartman, S. "An Agile Enterprise Reference Model". Available: http://www.parshift.com/aermodA0.html
10. English, L. "Defining Information Quality", Improving Data Warehouse and Business Information Quality,Wiley & Sons, New York, 1999.
11. English, L. Information Quality Improvement: Principles, Methods and Management, Seminar 5th. Ed., Information Impact International, Inc., Brentwood, Tennessee, 1996.
12. Frappaolo, C. "Defining knowledge management: four basic functions", ComputerWorld, February 1998
13. ICAM. "US Air Force Integrated Computer Aided Manufacturing (ICAM) Architecture", Part II, Volume IV-Functional Modeling Manual (IDEFO), Air Force Materials Laboratory, Wright-Patterson AFB, Ohio 45433, AFWAL-tr-81-4023, 1981.
14. Inmon, B. "Data Warehouse - Into the 90's", All About IRM'92 Conference, Beaver Creek, CO, July 1992.
15. Juran, J. Juran on Planning for Quality, Free Press, New York, 1988.
16. Karpe, Y., Hodge, G., Cahill, N. & Oxenham, W. "Information Engineering: Enhancing Decision Effectiveness in Textiles?", Proceedings of the 80th World Conference of the Textile Institute, Manchester, UK, April 2000.
17. Leibmann, M. "Building Knowledge Management Solutions: A Way to KM Solutions (Technical Deployment Guide), http://www.microsoft.com/solutions/km/KMSols.htm, Microsoft Corporation, 2000
18. Malhotra, Y. The Brint.com Knowledge Management Portal. http://www.brint.com/km/, 2000
19. Microsoft Corporation. "Digital dashboard Overview", Microsoft Solutions, http://agent.microsoft.com/solutions/km/Ddoverview.html, 2000

20. Microsoft Corporation (a). "The Microsoft Knowledge Management Strategy- Practicing Knowledge Management: Turning Experience and Information into Results (White Paper) http://www.microsoft.com/solutions/km/KMpract.htm, Microsoft Corporation, 2000
21. Nayar, M. "A Framework for achieving information Integrity", IS Audit & Control Journal, Vol. II, 1996.
22. O'Dell, C. "A Current Review of Knowledge Management Best Practice", Conference on Knowledge Management and the Transfer of Best Practices, Business Intelligence, London, December, 1996.
23. Petrash, G. "Managing Knowledge Assets for Value", Knowledge -Based Leadership Conference, Linkage, Inc. Boston, October 1996
24. Radding, Alan. "Executive Summary", Knowledge Management: Succeeding in the Information-Based Global Economy, CTR Corporation, SC, USA, 1998.
25. Strong, D., Lee, Y. & Wang, R. "Data Quality in Context", Communications of the ACM, Vol. 40, (5), May 1997.
26. Taft, D. "Stopping knowledge overflow", Computer Reseller News, Manhasset, February 2000.
27. Turban, E. Expert Systems and Applied Artificial Intelligence, Macmillan, 1992.
28. Van der spek, R. & Spijkervet, A. "Knowledge Management: Dealing Intelligently with Knowledge", Knowledge Management and its Integrative Elements, Liebowitz & Wilcox, eds., CRC Press, 1997.
29. Vernadat, F. "Enterprise Modeling and Integration: Principles and Applications", Chapman & Hall, London, 1996
30. Wang, R. & Kon, H. "Toward Total Data Quality Management (TDQM), Sloan School of Management, MIT, http://web.mit.edu/tdqm/papers/92, June 1992
31. Wang, R., Sotrey, V & Firth, C. ""A Framework for Analysis of Data Quality Research", IEEE Transactions on knowledge and Data Engineering, Vol. 7, (4), 1995
32. Wiig, K. "Knowledge Management: Where did it come from and where will it go?" Expert Systems with Applications, Pergamon Press/Elsevier, Vol. 14, Fall 1997.
33. Wizdom Software. "Introduction to Wizdom Software and Business Process Engineering", 1998

Correspondence Addresses:

Dr. George Hodge, Dr. William Oxenham and Yatin Karpe
College of Textiles, North Carolina State University
Raleigh, NC 27695-8301, USA

Mr. Neil Cahill
Institute of Textile Technology, 2551 Ivy Road
Charlottesville, VA 22903-4614, USA