AN INVESTIGATION OF THE UNIVERSE AND ANATOMY OF WORK

by

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(ABSTRACT)

This research study investigated eight specific work characteristics (outputs, inputs, work type, discretion level, work pursuit level, level of endeavor, decision type and maturity level), on three sub-populations of workers (production personnel, office/secretarial personnel, and university engineering professors). Thirty one production personnel from two organizations (the Print Shop and ABC Corporation-pseudonyms) located in southwest Virginia were used for the first group (B group). The second group (W group) comprised five office/secretarial personnel from an engineering department of a southwest Virginia university. The third group (K group) was made up of six engineering professors from three separate universities located in the eastern and midwest United States. The W and K groups used a self-logging data collection technique (cued by a random beeper) to record information about the work tasks being accomplished when cued. For the B group, a modified work sampling technique was used to gather the same information on work tasks as in the W and K group data collection. This information was compiled by an on-site analyst working from a random time table to cue workers for the required information.

The purpose of this research was to validate a specified work model (B/W/K). The design uses stratified sampling (homogeneity within strata and heterogeneity between strata).

A modified chi-squared statistical methodology (contingency table analysis) was used to analyze the data. The work definitions postulated by the B/W/K work model are supported by the research findings of this study. Specifically, four of the eight work characteristics (outputs, inputs, work type, and discretion level) of the work definitions were strongly supported by the results (p value $\ll 0.001$). The remaining four characteristics (pursuit level, endeavors, decision type and maturity level) showed strong results (some p values $\ll 0.001$), but some aspects of the sub-classifications of the work characteristics are questionable. Along with the eight work characteristics, this study provides detailed data on worker location, product / service, equipment usage, and knowledge data for all three work groups.

ACKNOWLEDGMENTS

This is probably the hardest part to write in a thesis or dissertation because so many individuals deserve recognition for the work that carries the name of one individual. I say this not show humility but the sincere realization that education, in most every form, carries a social mark. A dissertation is the culmination of a special teacher-student relationship. In its purest form it is the mentorship of knowledge, experience, and friendship that initiates a person in to the society of scholars. I have been privileged to have been granted this opportunity. Thus, I must first thank my committee chair, Pat Koelling, for all he has done. Pat and I met regularly at least once a week for several hours throughout my time at Tech. This dedication of his, I can only repay by treating my students with the same consideration and dignity. Pat is a quiet person who has the gentle ability to teach in a way that seems more like a casual conversation than a lesson. Pat has the rare combination of a good rigorous critical scientific mind and approach with an easy going manner. I hope I will be able to emulate this with my students.

The members of my committee: Bob Dryden, Scott Geller, Paul Kemmerling, Tarek Khalil, and Paul Torgersen, all played a crucial part in the development of this document and my PhD education. I feel proud to call myself one of their students. I want to mention a special man whose name does not appear on this document because he passed away before I was able to complete my studies. Marvin Agee was a member of my committee, a person I admired much. I remember fondly the many hours I spent talking with Dr. Agee in his corner office in the fifth floor of Whittemore Hall. He was a special man. A good old industrial engineer. I miss Marvin Agee and regret his signature could not be on this document.

An endeavor as all encompassing as a doctoral degree involves almost every part of a person's life. I must recognize the invaluable support of my family. My parents, siblings, children, and in-laws helped me in ways that are too lengthy to enumerate. I can only say thank you. My wife Ana Maria requires a special note. Not only did she provide the moral and psychological support so crucial to an effort such as this, but she typed the majority of this document, my pre-proposal, pre-lim exam, masters thesis, journal publications, term papers, etc., etc. I believe she deserves a doctorate 'honoris causa' for putting up with all of this. I also wish to thank the friends with which I studied here at Tech and who helped expand my thoughts which are reflected in this document. Specifically, thank you Paul Rossler, Maher Masri, Peter Phusavat, and Walthea Yarbrough.

Finally, I want to express my gratitude (thank God) for the opportunity to be able to study in an institution like Virginia Tech. We live in a time when society is undergoing many changes. Many people will never have even a glimmer of a possibility to attend an institution of higher education. This saddens and humbles me. I can only hope that the knowledge I have acquired here will be used in some small way to assist those not so fortunate. I part as I came,... thankful.

Mario G. Beruvides

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LIST OF TERMS

WORK CHARACTERISTIC	TERMS	DEFINITIONS
1- Output	Pbo	B work output tangibility probability
	Pwo	W work output tangibility probability
	Pko	K work output tangibility probability
2- Input	Pbi	B work input tangibility probability
	Pwi	W work input tangibility probability
	Pki	K work input tangibility probability
3- Work Type	Pbwp	B work work type physical classification probability
	Pbws	B work work type some physical classification probability
	Pbwm	B work work type mainly mental classification probability
	Pwwp	W work work type physical classification probability
	Pwws	W work work type some physical classification probability
	Pwwm	W work work type mainly mental classification probability
	Pkwp	K work work type physical classification probability
	Pkws	K work work type some physical classification probability
	Pkwm	K work work type mainly mental classification probability
4- Discretion Level	Pbde	B work discretion level little to none classification probability
	Pbdf	B work discretion level fair classification probability
	Pbdh	B work discretion level high classification probability
	Pwdl	W work discretion level little to none classification probability
	Pwdf	W work discretion level fair classification probability
	Pwdh	W work discretion level high classification probability
	Pkdl	K work discretion level little to none classification probability
	Pkdf	K work discretion level fair classification probability
	Pkdh	K work discretion level lhigh classification probability
5- Pursuit Level	Pbpc	B work pursuit level process classification probability
	Pbpj	B work pursuit level project classification probability
	Pbpg	B work pursuit level program classification probability
	Pbpb	B work pursuit level problem classification probability
	Pbpx	B work pursuit level perplexity classification probability
	Pwpc	W work pursuit level process classification probability
	Pwpj	W work pursuit level project classification probability
	Pwpg	W work pursuit level program classification probability
	Pwpb	W work pursuit level problem classification probability
	Pwpx	W work pursuit level perplexity classification probability
	Pkpc	K work pursuit level process classification probability
	Pkpj	K work pursuit level project classification probability
	Pkpg	K work pursuit level program classification probability
	Pkpb	K work pursuit level problem classification probability
	Pkpx	K work pursuit level perplexity classification probability

WORK CHARACTERISTIC	TERMS	DEFINITIONS
6- Endeavor	Pbef	B work Endeavor level functional classification probability
	Pbeo	B work Endeavor level operational classification probability
	Pbet	B work Endeavor level tactical classification probability
	Pbes	B work Endeavor level strategic classification probability
	Pwef	W work Endeavor level functional classification probability
	Pweo	W work Endeavor level operational classification probability
	Pwet	W work Endeavor level tactical classification probability
	Pwes	W work Endeavor level strategic classification probability
	Pkef	K work Endeavor level functional classification probability
	Pkeo	K work Endeavor level operational classification probability
	Pket	K work Endeavor level tactical classification probability
	Pkes	K work Endeavor level strategic classification probability
7- Decision Type	Pbts	B work decision type structured classification probability
	Pbte	B work decision type semi-structured classification probability
	Pbtu	B work decision type unstructured classification probability
	Pwts	W work decision type structured classification probability
	Pwte	W work decision type semi-structured classification probability
	Pwtu	W work decision type unstructured classification probability
	Pkts	K work decision type structured classification probability
	Pkte	K work decision type semi-structured classification probability
	Pktu	K work decision type unstructured classification probability
8- Maturity Level	Pbmv	B work maturity level visibility classification probability
	Pbmc	B work maturity level control classification probability
	Pbmo	B work maturity level optimization classification probability
	Pwmv	W work maturity level visibility classification probability
	Pwmc	W work maturity level control classification probability
	Pwmo	W work maturity level optimization classification probability
	Pkmv	K work maturity level visibility classification probability
	Pkmc	K work maturity level control classification probability
	Pkmo	K work maturity level optimization classification probability

CHAPTER 1

INTRODUCTION TO RESEARCH

"For more than a century, companies have moved manufacturing operations to take advantage of cheap labor. Now human capital, once considered to be the most stationary factor in production, increasingly flows across national borders as easily as cars, computer chips, and corporate bonds. Just as managers speak of world markets for products, technology, and capital, they must now think in terms of a world market for labor," (Johnson, 1991; p. 115). The need to study work has existed as long as man has toiled in the production of goods. Humans are distinguished from other animals by their use of tools and the complexity of their work. The research proposed in this document is an attempt to study work.

This research first examines the problems facing research in the broadly defined area of work (Figure 1.1). A literature (background) review of the concept of work is addressed in Chapter 2. Such issues as historical influences, philosophical conceptions, industrial developments, definitions, deficiencies, and types of work are addressed. This review leads to some potential avenues of research with respect to work (see Chapter 2). In Chapter 3, a formal confirmatory research design is presented in detail. This is followed by Chapter 4, where the field study results are presented. The results are analyzed in Chapter 5. Finally, conclusions (Chapter 6) and recommendations'(Chapter 7) of this research are presented.

In this chapter (Chapter 1), a brief history and background, research problem setting, research scope and limitations, importance of this research, projected outputs, and desired outcomes are presented (Figure 1.2). This chapter specifies the research purpose and objectives.

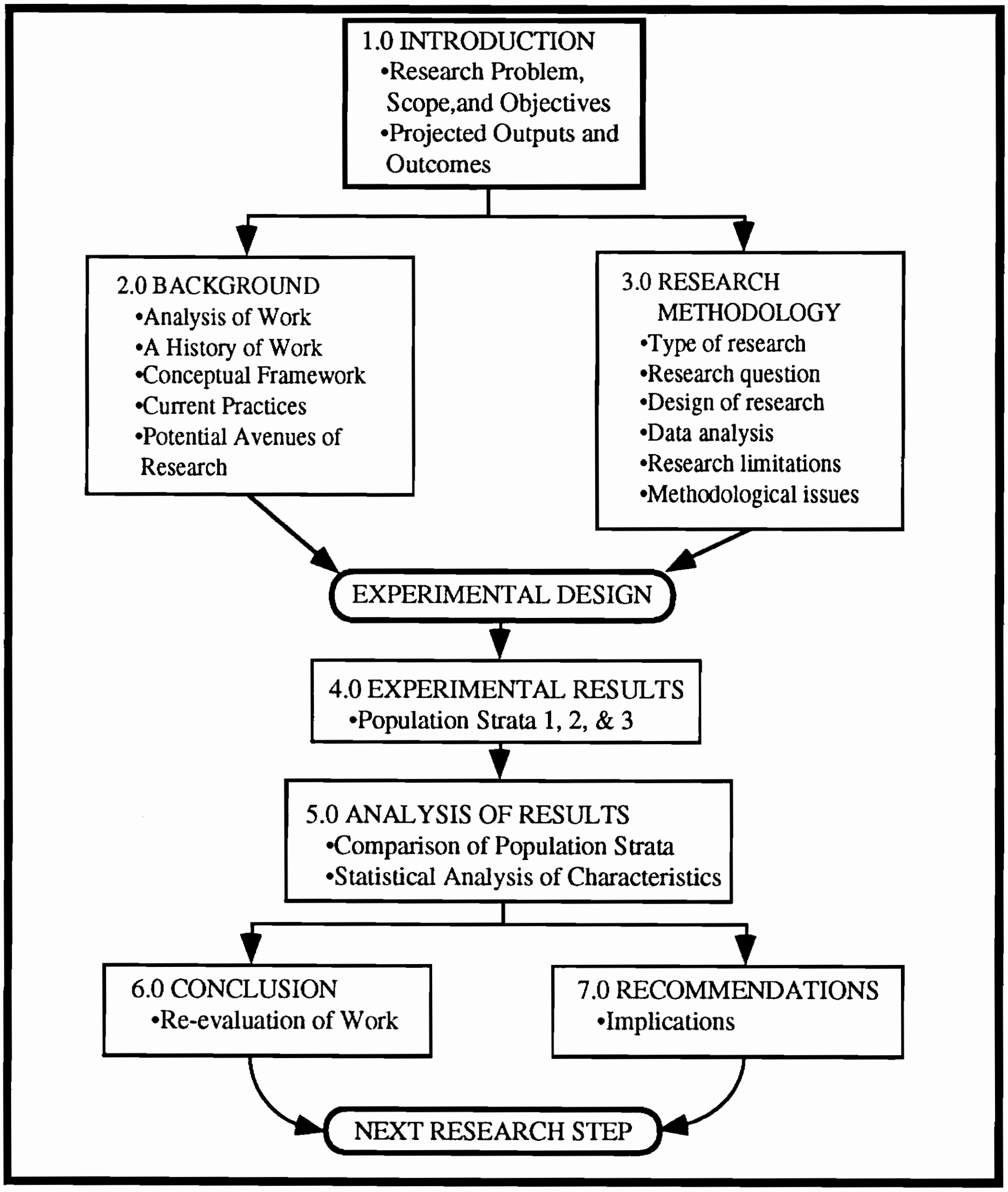

Figure 1.1 Thought Diagram for the Development of This Proposal.

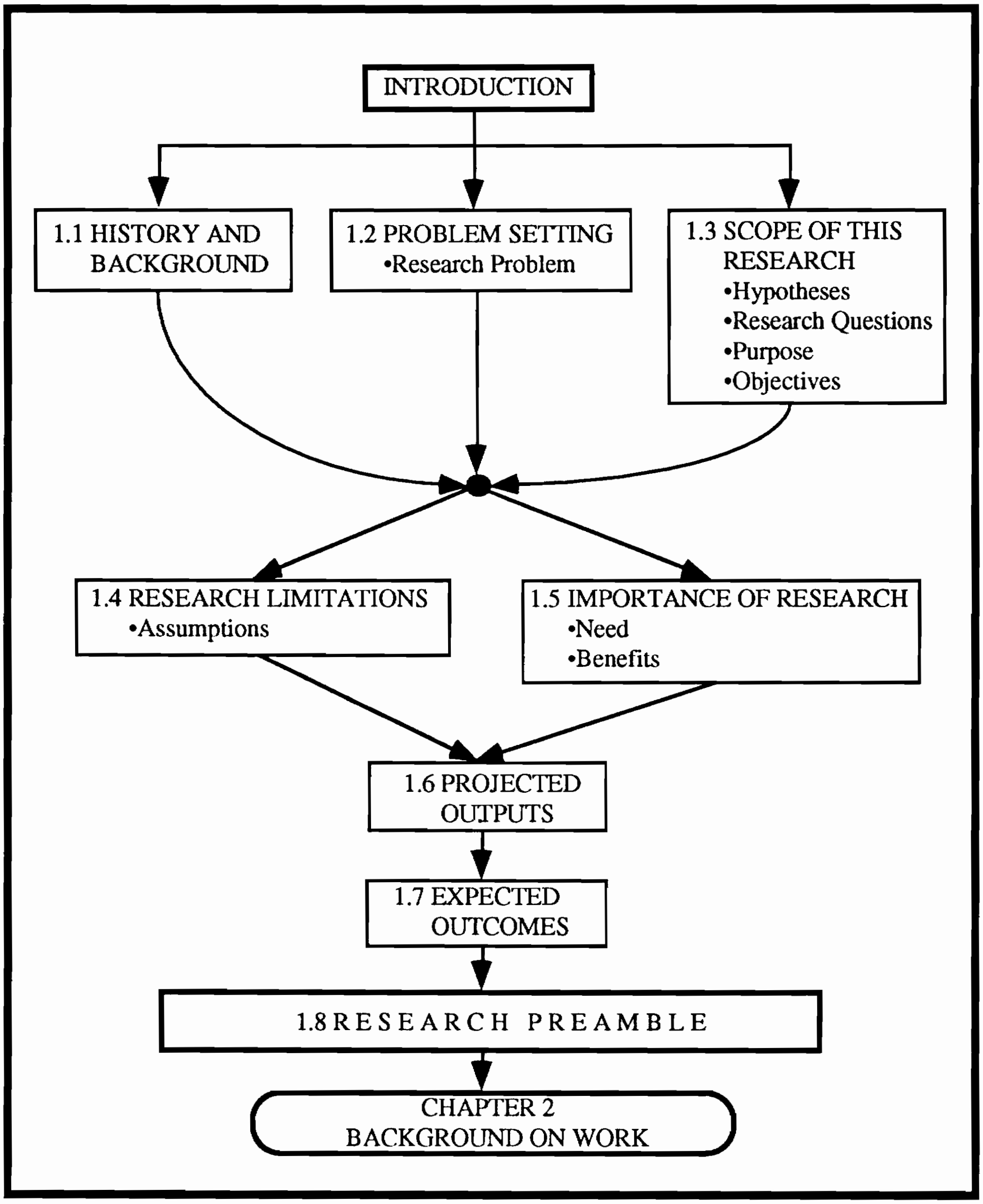

Figure 1.2. Thought Diagram for the Logical Development of Chapter 1.

1.1 HISTORY AND BACKGROUND

The nature of work has undergone drastic changes in the past several years. Such things as global markets, increased international competition, automation, self-managing work team schemata, employee ownership, worker cooperatives, quality control issues, etc., have caused us, as a society, and industrial engineers in particular, to question our perceptions of work.

The concept of work has profound ramifications. Critical problems, issues as mundane as work efficiency and effectiveness (how many bodies do we need to do this project?), and the volatility of a sensitive issue such as compensation, are based heavily on how we perceive and ultimately design work. Are the concepts, perceptions, and models of work we currently use what is needed to confront the societal and industrial needs of the present and the future? It is the contention of the researcher that they are not. Our conceptions of work are outdated and must be re-evaluated. Specifically from an industrial engineering standpoint, our paradigms are rooted in our Tayloristic beginnings (Taylor, 1911). These views - although many are of value - must be adapted and changed to meet new challenges and work environments that, frankly, Taylor never really had to deal with. The work we do says much about who we are. The concept of work can be seen as common ground when looking at the human race as we know it. Work is indelibly etched into the fabric of man's culture.[1] The concept of work, in a general sense, is easily understood by all members of our and other societies. But the concept falls short from being fully defined in a formal sense. Ruiz-Quintanilla and Wilpert (1988), state that the "'[m]eaning of working', although in use in social science literature for more than thirty years, still lacks rigorous conceptualization," (p. 3). This

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[1] By this it is meant all cultures that make up mankind as we know it. To the author's knowledge, some form of work is practiced in all known cultures.

study analyzes the concepts of work and practices, and presents a research agenda in which to further develop this elusive concept.

Measuring and evaluating human resources has and always will be a major concern to most every industry. In the past, the measure of labor was restricted to what is termed 'blue-collar' work. There is a need to expand beyond the scope of the blue-collar labor productivity concept to what many refer to as 'white-collar' work and 'knowledge' work. The fundamental change in the U. S. economy from a manufacturing to a service-oriented economy is the driving force behind this need. As existing industries become more service-oriented, there is a greater proportion of white-collar workers entering the work force. Peter Drucker (1974) puts it very boldly, "the manual worker is yesterday-and all we can fight on that front is a rear guard action. The basic capital resource, the fundamental investment, but also the cost center of a developed economy is the knowledge worker who puts to work what he has learned in systematic education, ideas, and theories, rather than the man who puts to work manual skill or muscle." In a sense, managing people has become a management of technology issue.

"The technological future is inevitable. However, the successful introduction, adoption, implementation, and maintenance of advanced technology heavily depends on the people who are part of this revolution," (Ozatalay and Reilly, 1990, p. 749). Ozatalay and Reilly touch upon a critical point in the management of technology; human resource management. Technology is transforming the way we do business. But it is also transforming the type of resources we need to do business. Human resource demands have changed; so must the way we manage workers change. For this we must better understand work itself.

Defining work in a way that is operational (from an industrial engineering stand point) is crucial.[2] Work has been defined in many ways. The definition of work can be approached from a philosophical, physical, human factors, and industrial stand point.[3] The emphasis of this research ultimately is to address work from an industrial engineering perspective. The proposed research relies heavily on the B, W, and K work model (Beruvides and Koelling, 1992a, and b; Beruvides, Omachonu, and Sumanth, 1989; Beruvides and Sumanth, 1987). This model defines three types of work (B-work, W-work, and K-work) along eight different dimensions. These dimensions being, 1- the tangibility of outputs, 2- the tangibility of inputs, 3- the nature of the work (physical/mental), 4- the discretion level involved, 5- the uncertainty level of work tasks, 6- the comprehensiveness of work endeavours, 7- the decision structures used to do work, and 8- the maturity level or stage of the work (Beruvides and Koelling, 1992b).

1.2 RESEARCH PROBLEM SETTING

There is an infinite variety of possible problem settings in which to address the subject area of work. Work has been defined, researched, and studied in a variety of ways and using a plethora of approaches. There are physical, philosophical, industrial, human factors, and sociological approaches to addressing work. All lend and contribute to our understanding of work. No one approach is better than another for they all attack the subject from a decidedly different set of priorities. It is the view in this research that any approach to the study of work needs to incorporate, or at least understand, each work

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[2] An old management adage states that 'you can not manage what you can not measure. And you can not measure what you can not operationally define.' Operational definitions are essential to our work as industrial engineers.

[3] The variety of work definitions will be covered in detail in chapter 2.

paradigm so as to render a more wholistic view of the subject. So, even though this research is specifically from an industrial engineering perspective, other academic approaches are studied and reviewed to give this work a wholistic approach to the research on work.

1.2.1 RESEARCH PROBLEM.

Specifically, the definition and subsequent specification of work itself is addressed in this research. From an industrial engineering standpoint, a person would be hard pressed to find a subject matter that better defines the industrial engineer than work itself. The works of Taylor (1911, 1907, and 1903) and the Gilbreths (F. B. Gilbreth, 1914, 1911, 1909; F. B. Gilbreth and L. M. Gilbreth, 1919, 1917; and L. M. Gilbreth, 1914), the founders of industrial engineering, are based heavily on the attempt to understand and thus better design industrial work. It is a bit perplexing that a profession so steeped in the essence of work has no comprehensive definition or conceptualization of the subject[4]. So this is the research problem here addressed: what are the components of work?

1.3 SCOPE OF THIS RESEARCH

The scope of this research is to review what we know about work from a variety of possible and logical avenues, and then funnel this knowledge into a comprehensive conception of work. That is, bring together as much as is known about work from the

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4 We must note that from a human factors - ergonomics standpoint, definitions do exist. But there is no comprehensive industrial conception of work. This is not to say that an enormous amount of excellent work has not been done on work, only that there has not yet been a comprehensive effort to unite what we know about the subject of work.

relevant subject areas and portray both a working set of definitions and a conceptual model that are scientifically researchable from an industrial engineering standpoint.

1.3.1 RESEARCH QUESTION.

The general questions addressed by this research are: What is work? And, how do we define work? More specifically:

1. What do we, as a community of scientists, know as the concept of work?

2. How can we define industrial work, in an operational sense, so that it is functional to us[5] in determining and ultimately designing work?

3. Is there more than one type of work? If so, what are the determining characteristics between the different types of work?

4. Based on the answer to question 2, what are the specific components or elements[6] that comprise or make up industrial work?

5. Based on the answer to question 4, how do the 'components or elements' define and distinguish work?

1.3.2 HYPOTHESES TO BE EXAMINED.

This research will examine one main hypothesis and eight sub-hypotheses. The eight sub-hypothess correspond to the eight parts of the B, W, and K work model (to be presented in Chapter 2). The combined eight sub-hypotheses form the theoretical basis that supports the main hypothesis.

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[5] This refers specifically to industrial engineers, and in a general sense to managers and other industrial scientists.

[6] The terms components or elements are used here in a loose sense. The terms are not meant to be concrete and specific items, but descriptive parts that help us better define work.

Main Hypothesis- The three types of work (B, W, and K) are different along the 8 integral characteristics (outputs, inputs, type, discretion level, persuits, evdeavors decision type, and maturity level) that define work.

Sub-hypothesis 1- The outputs for B-work are mainly all tangible; those for W-work are mainly tangible but less so than for B-work; and the outputs for K-work are mainly intangible.

Sub-hypothesis 2- The inputs for B-work are almost all tangible; those for W-work are mainly tangible but less so than for B-work; and the inputs for K-work are mainly intangible.

Sub-hypothesis 3- The work type for B-work are almost all physical in nature; the work type for W-work is a mixture of physical and mental; and the work type for K-work is mainly mental in nature.

Sub-hypothesis 4- The discretion level for B-work is low; the discretion level for W-work is moderate; and the discretion level for K-work is high.

Sub-hypothesis 5- The work pursuits for B-work range mainly from process to project in nature; those for W-work range mainly from project to program in nature; and the work pursuits for K-work range mainly from programs to perplexity.

Sub-hypothesis 6- The work endeavors for B-work range mainly around the functional to operational level; those for W-work range mainly from operational to tactical; and the work endeavors for K-work range mainly from tactical to strategic in nature.

Sub-hypothesis 7- The decisions in B type work are mostly structured in nature; those for W-work are mainly semi-structured; and the decisions for K-work are mainly unstructured in nature.

Sub-hypothesis 8- The maturity level encountered in B-work ranges from visibility to control in nature; the maturity level encountered in W-work ranges from visibility to control; and the maturity level encountered in K-work ranges from control to optimization in nature.

1.3.3 RESEARCH PURPOSE.

The purpose of this research is threefold. First, this study is an attempt to better understand the concept of work. To do this, an extensive literature review and analysis of work was undertaken. This literature review ventures out of the normal realm of the industrial engineering literature because the subject area requires it. Secondly, this document presents a work concept (model) on which the research is based. This model is a component of a research agenda (program) that is projected to encompass several years of effort into the analysis of work. Finally, this document presents a field study that develops and answers a specific research question (confirmatory study) as a first step in the research agenda proposed on work.

1.3.4 RESEARCH OBJECTIVES.

The objectives of this research can be divided into long term and short term objectives. The long term objective of this research is to develop and initiate a research agenda (program) for the formal academic study of work. The short term objective is to initiate the research agenda on work by conducting a rigorous scientific study on the first stage of the research agenda (see Chapter 2 for the development of the research agenda on work).

1.4 RESEARCH CONCERNS

All research efforts are limited in their scope in some way. This research effort has several limitations.

1- The research is based on a specific work model (Beruvides and Koelling (1992a and 1992b). This, although focusing the research, also confines the research to a specific paradigm.

2- The subjects used were selected from various job types (refer to Chapter 3 for a full description of the subject types). All possible work types can not possibly be encompassed.

3- The selection of subjects used in this research was based on the researchers perception of job classifications that serve as best cases (exemplars) of each type of work. This was a judgment call on the part of the researcher since these definitions have never been tested or validated (only face validity has been used).

4- Due to time and cost limitations the study was done in a 'between group' analysis (B-work, W-work, and K-work). With-in group analysis (such as looking at several possible graded classifications of, say, W-work only) will be left to future studies.

1.4.1 ASSUMPTIONS UNDERLYING THIS RESEARCH.

All rearch studies have implicit underlying assumptions. So as to assist the reader and the researcher to better comprehend the research to be undertaken, the assumptions for this research are as follows:

1. The definitions of the three work types (B, W, and K work) have been empirically developed from an extensive literature search and the researcher's own

observations of over 10 years of work experience in industry. The definitions are assumed to be representative (from a face validity stand point) of industrial work.

2. This research is based on a work task analysis of individuals who are judged by the researcher to be representative of one of the three major work types. Inherent in this assumption are two sub-assumptions:

   2a. that the individuals' work (job classification and tasks) are truly representative, and

   2b. the inherent differences between subjects are random and are not significant and influential to the results obtained.

3. The complexity of a concept, such as work, can be operationally defined and modeled in such a way that is suitable for scientific analysis.

4. No research can claim absolute or final causality when dealing with such complex and multidimensional concepts as work. Thus, treatments and outcomes can not be viewed as singular and unconstrained (Palton, 1986; Suchman, 1967). It is assumed that a reasonable estimate and statistical significance (if achieved in the results) do represent an effectual relationship.

5. The basis of this research is a set of definitions that, although considering a variety of fields of study (philosophy, human factors, etc.), is strictly industrial engineering in nature. Thus, it is assumed that even though this research emphasizes an industrial engineering perspective, that perspective is representative enough of the whole so as not to be naive, but still narrow in its focus as is required by a study of this nature.

1.5 IMPORTANCE OF THIS RESEARCH

This research is important because there is a current relevant need and potential benefits to be derived from its completion.

1.5.1 NEED FOR THIS RESEARCH.

The need for this research is both theoretical and practical in nature. As noted previously in this document, the meaning of work, although under study for more than thirty years, is lacking in rigorous conceptualization (Ruiz-Quintanilla and Wilpert, 1988). This lack of conceptualization is evident not only in the social sciences, but is a hinderance from a practical industrial standpoint. The many changes, experiments, and problems that are evident in the scholarly as well as popular journals attest to the void that exists (see Chapter 2). From a practical view, we also see the many changes, problems, and controversies portrayed almost on a daily basis with the many work schemes proposed and attempted by corporations. Two very relevant issues to arise recently have been labor disputes between both Caterpillar Corporation and General Motors with the UAW (see Business Week, 1992b; Kelly, 1992; Michell and Templin, 1992; Miller, 1992; Patterson, 1992; Patterson and Rose, 1992; Rose, 1992; Rose, 1991; Rose and Patterson, 1992 a, b; Woodruff, 1992; and Templin, 1992b and c). There are many other issues currently debated on work; the U. S. work ethic (see Davis and Milbank, 1992; Chipello and Templin, 1992a; and Morganthaler, 1992); flexible work schemes (see Trost, 1992; and Schlesinger); white-collar downward mobility (seeNussbaum et. al., 1992; Pearl, 1992; and Lublin, 1992); as well as a mosaic of related issues such as 'industrial migrants' and middle class worker erosion (see Ansberry, 1992;

Horwiltz, 1992; and Milbank, 1992).[7] There is a real need to better define and understand work.

1.5.2 BENEFITS OF THIS RESEARCH.

The reason for conducting this research is multi-faceted. First, it contributes to the body of knowledge, benefiting researchers (in industrial engineering as well as other related fields), practitioners (managers, industrial engineers, personnel administrators, etc.), as well as students of the subject matter. This contribution expands the body of knowledge by assisting in better understanding the concept of work. Secondly, this research provides a more detailed definition and conceptualization of work that could influence our industrial practices in analyzing as well as designing work tasks or jobs. Thirdly, although the methodology is not new or revolutionary, it is a different approach to work analysis that may be found to be useful to the practicing engineer or analyst. Finally, this research benefits the field of industrial engineering by challenging us to re-evaluate the concept of work, which is intrinsically linked to our profession's past, present, and future.[8]

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[7] These many citations are but a fraction of the articles and issues currently being debated about how we do work. For those interested in other articles on the many facets of work currently being debated, explored or commented on, see Baker, 1992; Baker, Woodruff, and Weiner, 1992; Brennen, 1992; Deveny, 1992; Ferguson, 1992; Keller, 1992; and Machalaba, 1992, to mention a few.

[8] The author would venture to say that no one concept underlies the basis for industrial engineering as does work. The study, analysis, and design of work defines us as a profession.

1.6 RESEARCH OUTPUTS

This research generated several outputs. Specifically, the outputs are, first, an updated literature review of work. This literature review is an in-depth compilation of the research and conceptions of work from a physical, historical, philosophical, sociological, and industrial perspective. Secondly, this research produces a specific research agenda (program) to further the knowledge of the study of work (see Chapter 2). The research agenda is structured in the form of an inference tree to help guide the research process on work. Finally, this research generates a specific research project (the first step of the research agenda - see Chapters 3 through 6) that is an analysis of the B/W/K work model (Beruvides and Koelling, 1992b).

1.7 DESIRED RESEARCH OUTCOMES

The desired outcomes of this research are linked directly to the outputs. The literature review provides a historical, sociological, philosophical, and industrial perspective to the concept of work, resulting in a more complete understanding of work itself and a comprehensive reference source of the literature on work. The outcome of the research agenda is to focus research efforts on work for the near future (the next 3 to 5 years). The inference tree is a specific research plan in which to methodically as well as scientifically chip away at the study of work. The outcomes of the specific research study (dissertation) presented here are (1) a different application (research methodology) in which to research work (using traditional methods - timing mechanism and work logs), (2) a quantifiable understanding of the B/W/K work model, and (3) a better understanding of the concept of work. The research methodology is a specific written methodology with detailed work log forms, data tabulation sheets, equipment (timing mechanism), and specific data analysis (statistical analysis method). This outcome results in an industrial engineering tool for job analysis. The second outcome of the research study quantifies the B/W/K work model. Finally, this increased our knowledge base in the area of work research.

1.8 RESEARCH PREAMBLE

The research introduced here is specific and detailed. But a note must be addressed to the readers to prepare them for the approach taken in this research to accomplish the goal of defining and specifying industrial work. This study first looks at work through a very broad lense encompassing what at times will seem unrelated details (historical, philosophical, sociological, and industrial renderings of the concept of work). To this the author can only ask for the readers patience and understanding. The following chapter (Chapter 2) is designed specifically to funnel the knowledge compiled thus far on work to a workable core to achieve the objectives of this research.

CHAPTER 2

BACKGROUND ON WORK

In this chapter a review of the literature is provided.[9] The purpose of this chapter is to present the history and the many facets of work (figure 2.1). First, in section 2.1, a brief history is presented to put the concept of work into the context of this evaluation. This is followed by section 2.2 where the concept of work is presented as a critical area of study for all of engineering. In section 2.3, the concept of work is further detailed by investigating the psychological, philosophical, economic, and industrial engineering aspects that compromise the concept. In section 2.4, a 'working' or industrial perspective is undertaken that builds on the exposition provided in section 2.3. Here, productivity, the Universe of Work concept, and the measurement-vs-implementation dilemma are investigated. Sections 2.3 and 2.4 provide the basis for section 2.5, where the B/W/K work model is described. The B/W/K work model is the core model or conceptualization on which this research is based. The chapter concludes with sections 2.6 (Methods of

[9]This chapter looks at the concept of work from a variety of different perspectives (psychological, philosophical, physical, economic, industrial, and business procedures). Although it is impossible to go into much depth in each of these subjects matters, the author believes that each must at least be addressed to get a better overall picture of the concept itself. The emphasis of this research is on industrial engineering. This chapter is expected to funnel the many facets of work to focus on the main theme of this research, the B/W/K work model.

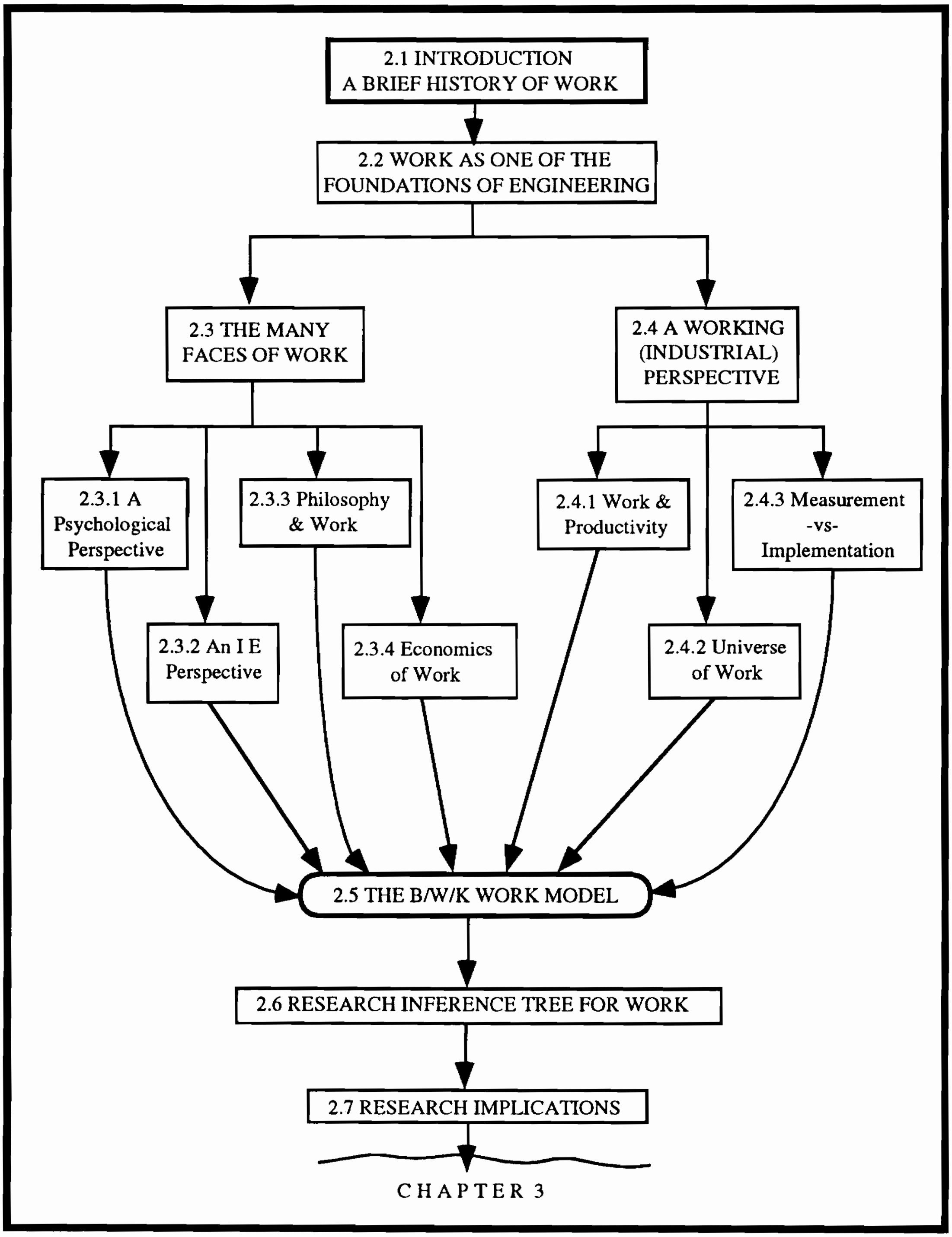

Figure 2.1 Thought Diagram for the Logical Development of Chapter 2.

researching Work), 2.7 (Research Inference Tree for Work) and 2.8 (Research Implications), where the research agenda that drives this research is presented, discussed, and analyzed.

2.1 INTRODUCTION: A BRIEF HISTORY OF WORK

The work we do says much about who we are. The concept of work can be seen as common ground when looking at the human race as we know it. The concept of work, in a general sense, is easily understood by all members of our and other societies. [10] But the concept of work is far from being stagnant or monolithic. The concept of work has evolved and continues to evolve. Even though most all members of the human race understand what work is, there exist many variations and views of what contitutes work.

The meaning of work is different when compared across different societies. The Europeans view the terms work and labor (to toil) as different (Arandt, 1958). This distinction is evident in several civilizations. Labor is thus seen as the physical activities needed to fulfill the basic needs to sustain life (food, shelter, etc.). Work is seen differently. Work connotes activities related to cultural or aesthetic activities that may or may not produce a product or service (Nadler, 1963). In this country the terms are used more interchangeably, but the term labor is usually reserved for unions.

Historically, humans had to work to survive (hunt, forage for food, make clothing). Through time, humans evolved from hunter-gatherers to farmer-herders. This change created the need for planning and a more complex division of labor (or work). This division of work led to a formation of rank ordering of work (Nadler, 1963).

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[10] By this I mean all cultures that make up mankind as we know it. To my knowledge, some form of work is practiced in all known cultures.

Physical or manual work was viewed as tedious and distasteful and not as important or desirable as cultural, religious, or mental activities. This gave rise to the use of slaves as labor providers for menial or tedious work. This division or ranking of work is seen as early as the Greek and Roman civilizations (Nadler, 1963).

Changes did occur with the perception of work in the reformation period in Europe. Martin Luther viewed work as a way to honor God. This concept was extended by Calvin, who saw work as honorable and purifying, and led to what we know as the protestant work ethic. This conception of work was, of course, brought to the U. S. with the first settlers (Pilgrims). It had a profound influence on the American view of work. As Kranzberg (1959) puts it, "[m]anual labor [is] not a thing to be despised but rather an indispensable prerequisite for the great American dream of success."[11]

Thus, we see a completely different view of societal perception toward work. Or as Nadler (1963) would put it: "[w]ork in our society has come to represent both a means and an end to man" (p. 6). Nadler thus believes that to study work one must analyze the purpose of the work itself. He represents this as a cycle (figure 2.2), the cycle being individual enterprise leads to greater productivity, which in turn renders a higher standard of living, which increases human dignity, which closes the cycle and begins a cyclical spiral by influencing individual enterprise.

[11] Cited in Nadler (1963) on page 6.

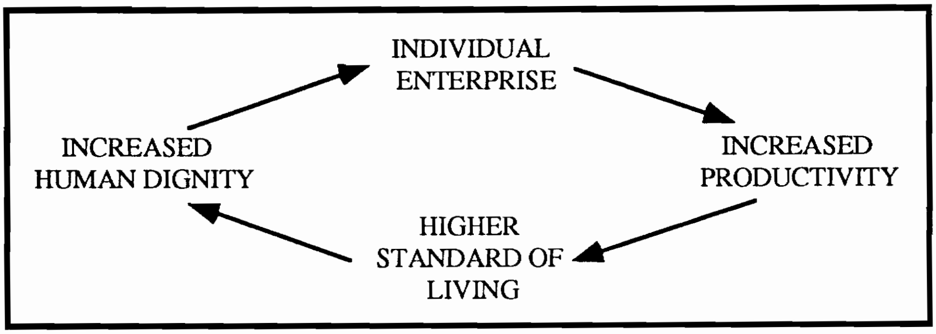


Figure 2.2 Circular Pattern of Work Purpose. (From Nadler, 1963).

Historically, our perceptions of work have changed and influence our current thinking. Likewise, psychological, philosophical, economic, and industrial influences have shaped and are shaping our views on work.

2.2 WORK AS ONE OF THE FOUNDATIONS OF ENGINEERING

The word 'work' has many meanings. Beruvides, Omachonu, and Sumanth (1989) found that work has been defined in physical terms (laws of physics), from a thermodynamics perspective (heat), from a human factors perspective (bodily response), from a philosophical perspective, and an industrial perspective.[12] This study will look at these different perspectives to get a better understanding for work. Before the concept of work is analyzed in this document, it is important to note that work is a unifying concept for the field of engineering. From the mechanical engineers analysis of force acting through displacement, or the study of thermodynamics; the chemical engineers study of work done by chemical energy; the civil engineers study of the potential and

[12] Much of the following section is based on the work of Beruvides, Omachonu, and Sumanth, (1989).

kinetic energy; the electrical engineers analysis of power engineering; and the industrial engineers domain of work as it pertains to the study of humans (be it physical analysis -human factors, or the study of people doing work in industry -methods engineering). Work is a foundational as well as a unifying area of study for all engineering, crucial to all engineers. This research emphasizes this belief.

2.2.1 A PHYSICAL SCIENCE PERSPECTIVE

There are many grades to the concept of work. From a physical perspective, work is measured by the physicist as any force acting through a displacement. Thermodynamically, a work cycle is proportional to the heat cycle generated by the system being analyzed (Holman, 1976; Threlkeld, 1970, and Van Wylen and Sonntag, 1978). Thus, work can be measured by the amount of energy consumed or expended. These descriptions of work are cursory, but they portray definitions and descriptions of work that are integral parts of the knowledge of the engineering and science community as a whole.

2.3 THE MANY FACETS OF WORK

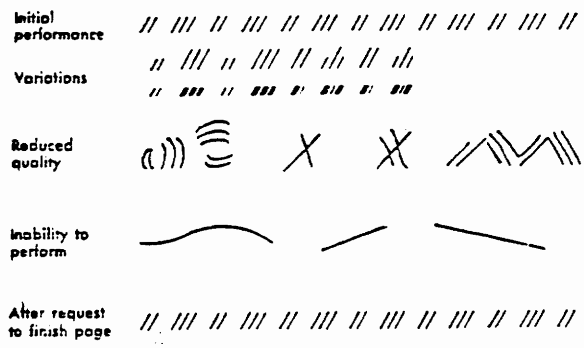
From what we have covered thus far, the concept of work is dynamic and multifaceted. There are in fact many ways to define, analyze, and study work. In this section, some psychological, industrial, philosophical, and economic ideas will be covered. These will serve as the underpinning for the B/W/K work model.

2.3.1 A PSYCHOLOGICAL PERSPECTIVE

The psychology of work measurement is a complex topic. The white-collar/knowledge worker is perceived as different from the production worker, not accustomed to being measured and not readily accepting measurement (Ruch 1982). The differences between blue-collar and white-collar or knowledge workers are often confused or not well understood. No doubt the work tasks of each type of worker are different. But the contention that the psychology of the workers is different is debatable. People are more probably similar than not. All workers have the same apprehensions about being measured.

Maier (1965) describes work done in the 1930's by industrial psychologists on monotony, boredom, and satiation. The study took a group of college students who were asked to draw vertical lines on a sheet of paper and to follow a specified certain pattern such as alternately grouping the lines in twos and threes. The subjects were not allowed to rest when doing this task (figure 2.3). The results show variations in the patterns degraded. The average subject reached a state of what psychologists term satiation after about four hours.

The experiment was repeated on a group of unemployed men (paid a small sum per hour to serve as subjects). The second group worked a full eight hour day with no noticeable degradation in work quality. Unlike their college counterparts, the unemployed production workers found the work to be pleasant. According to researchers the difference in performance of the workmen to that of the college students was found to be due to the difference in the way the work appeared to each of the subject groups. For the unemployed workers, the work period was fixed; the college students felt that the work was going nowhere.



The first row shows vertical lines, alternately grouped in twos and threes, properly executed. The second and third rows show changes occurring in the stage characterized by variation. The fourth row illustrates reduced quality. The task is no longer executed according to the spirit of the assignment although the person could argue that he has grouped lines in twos and threes. Thereafter the performance deteriorates even more until the person is unable to write. When asked to complete the page, however, the ability to execute the task is restored, as shown in the last row of lines.

Figure 2.3: Changes in Task Performance Accompanying Satiation (Maier 1965).[13]

The researchers concluded that the absence of the experience of a goal or an end seems to be the cause of satiation. Thus, satiation may depend completely upon the way one views the work.

This is one of the major differences in the working conditions of blue-collar and white-collar/knowledge work. The immediacy of work goals or objectives seems to be a critical issue in defining and determining work.[14] Blue collar work is more easily measured and is short term in nature. Most white-collar and knowledge work is long term in nature (long time frames), making it more difficult to supervise or review. Thus,

13 Cited in Beruvides, Omachonu, and Sumanth (1989).

14 This relates to Nadler's (1963) emphasis on the purpose of work. The purpose of a job task may determine much of how we view and ultimately define work.

any attempt to measure white-collar/knowledge work in the way blue-collar work is measured is futile and disconcerting to the workers.

2.3.2 AN INDUSTRIAL ENGINEERING PERSPECTIVE

This section will emphsize the various ways in which work is addressed by industrial engineers. Both the human factors and industrial perspective are covered.

2.3.2.1 The Human Factor

When looking at work from a human perspective, the work of psychologists and industrial engineers (what is commonly known as 'human factors' research) emphasizes such physical (body) exertion measures as EMG (electromyography), heart beats per minute, or oxygen consumption in kilocalories consumed per minute (McCormick and Sanders, 1982; LeVeau, 1977). Human factors engineering is concerned with the design of the work place so that the worker's optimal performance is achieved through a safe, ergonomically sound, and physiologically proper work place as well as a properly functioning work place. Thus, work from this perspective is concerned and defined with physical excertion as the key issue.

2.3.2.1 An Industrial View

From an industrial engineering standpoint, Turner, Mize, and Case (1978) see the job structure as a complement of tasks that combine to make a 'position.' Similar positions make up what we would think of as a job. Turner, Mize, and Case use the following descriptions.

> A **task** is human effort exerted for a specific purpose such as sharpening pencils or sweeping floors.
>
> A **position** is a collection of all the tasks performed by or requiring one person, such as that of a janitor.

A **job** is a group of positions highly similar or identical (an example being janitors).

We see from an industrial engineering (IE) perspective that work can be classified as a sequence of tasks, positions, and jobs. This in effect gives us another description of work that is not physical, physiological, or psychological in nature, but suited for industrial purposes.

2.3.3 PHILOSOPHY AND WORK

The concept of work is also treated extensively in the philosophical literature. Although it is out of the realm of this document to detail the myriad of philosophical nuances dealing with work, we will present two specific philosophical thoughts, those being the work of the English philosopher John Locke and the German philosopher Karl Marx.

2.3.3.1 The Fundamental Rights of Man

Philosophically, work or labor has been examined from a variety of angles. John Locke (1952)[15], the 17th century English philosopher, equates work to property. Property is seen by some philosophers as one of the three fundamental natural rights of men and women. These three fundamental rights being life, liberty, and property. Being fundamental rights, life, liberty, and property are viewed as crucial. Thus work, as linked to property (as we will see in the next section), is also a crucial element in the human condition.

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15 The work of John Locke was published in the 17th century. The source used for this study is a reprint of Locke's work.

2.3.3.2 Labor Theory of Property

Locke believes that if an apple tree is in the middle of a meadow or plot of land (the land belonging to no one, that is, it belongs to all; a gift from God), all men and women have equal right to the tree's fruit. Now if one particular individual were to go and trim the tree, and weed, fertilize, and water the ground around the tree (in effect do work on the tree), this person, by virtue of their work, can claim the tree as theirs. Thus, work is the basis for acquiring property. This is known as the 'Labor Theory of Property' (see Lemos, 1986). This conception is critical in that it lays the foundations of 'economic man and woman' as we know it today. Note again, work being the cornerstone to this idea.

2.3.3.3 Alienation

The Marxist philosophy views work in a different sense (Marx, 1844). This document will not go into depth on the many variations of Karl Marx's views because they involve a myriad of complex issues that are not seen as relevant to this discourse.[16] There is one concept that Marx developed which, if taken out of the context of 'class struggle,' is enlightening to the current industrial work environment; alienation.[17] If we accept that mass production alienates the worker from his work due to poor work design, then it is not a far leap of the imagination to see that this could, as Marx pointed out, lead to the worker being alienated from his fellow workers. These two 'psychological'

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16 These being the complexities of class struggle and the issues of Hegelian dialectic with respect to society and the evolution of man from a capitalist to a socialist being.

17 Taking alienation out of the context of 'class struggle' may be impossible and incorrect. The author believes that alienation does explain a current phenomenon in modern industrial society (that of job designs that alienate the worker from the pride of his/her work). The alienation is not necessarily a result of class struggle but, perhaps in part, more a result of bad job designs. This is more a problem of poor work practices than anything else. In fact, the work of W. Edwards Deming ("Out of the Crisis," 1982) in part addresses this issue. Point number 12 of Deming's 14 points for management is the removal of barriers that rob the worker of his/her pride of workmanship.

dilemmas can thus be seen as finally alienating the worker from him/her self (Marx, 1844; Fromm, 1991). By no means is this an attempt to psychoanalyze our current industrial society, nor is this research hinting in any way to a complex array of class struggle issues. But many of the current trends in the work environment, such as self managing work teams, worker cooperatives, and employee ownership, attest to the need to redesign our work environment. It many times appears that workers are being alienated from their work, not by anything as complex as class struggle, but by poor job design. This poor job design reflects not only on the labor-management relationship but also has ramifications on the economics of the workplace.

2.3.4 THE ECONOMICS OF WORK

The philosophical concepts reviewed above have implications on the economics of labor or work as we know it. The value theory of property is a central issue to capitalist economics. Alienation, as well as most of Marx's work, is the basis for communist economics. Since this research is based on the workplace as structured in a capitalist economy, the ensuing presentation will exclude any analysis with respect to communist economies.

2.3.4.1 Demand Theory of Value

Lemos (1986) combines the labor theory of property developed by John Locke with the 'Demand Theory of Value' which states that the economic value of an item is determined solely by what a person or a group of people are willing to do or exchange in order to obtain it. These two concepts (the labor theory of property and the demand theory of value), Lemos believes, represent the current capitalistic view of work economics. Lemos describes the economic value of labor as determined entirely by the economic value of what it produces. This, in effect, says the value of labor is dependent only upon its output. Thus, instead of labor determining the value of what it produces, it is the product (or output) that determines the value of labor.

2.4 A WORKING (INDUSTRIAL) PERSPECTIVE

Thus far, we have explored physical, psychological, industrial engineering, philosophical, and economic traits of work. Economically, the work of men or women (that is their economic value) is linked directly to the product or output. At this point we need to explore a closely related subject, that of productivity, so that we may better understand work and its possible definition.

2.4.1 WORK AND PRODUCTIVITY

To define and quantify work has, and will continue to be, an important factor for management. This is vital information for any manager. Blue collar work productivity has been well defined and analyzed (Sumanth, 1984; 1979). The challenge has been to define and measure white-collar and knowledge productivity.

White collar/knowledge work productivity has various characteristics that makes it unique from blue-collar work productivity. Characteristics such as discretion, decision making, design, organization, measure of output, long time periods for work completion, and non-repetitive nature of work cycles are but a few of the differences from traditional blue collar work that makes this type of work hard to analyze. In this section the development of some definitions of work and the major problems in measuring productivity for non-traditional work tasks are examined.

2.4.1.1 A Search for Definition

Measuring and evaluating human resources is a major concern to every industry. The measure of labor productivity in the past was restricted to what is termed 'blue-collar' work. In fact, the traditional definition of productivity is the ratio of outputs to inputs (Kendrick and Creamer, 1965; Sumanth, 1984 and 1979; and Sink, 1985). This definition of productivity is well suited for blue-collar work, where outputs and inputs are easy to distinguish. This is not the case for white-collar or knowledge work.

William Ruch (1982) gives two dimensions that distinguish knowledge work: discretion (the judgment at times required in some work tasks), and the degree to which a physical (tangible) product is involved in the process. The second of Ruch's dimensions (the degree to which a tangible product is involved in the process) makes the traditional equations for productivity seem awkward and at times useless. To establish viable measures for white-collar and/or knowledge work requires that many obstacles be overcome. The first thing required is definitions of these three different types of work.

2.4.1.2 Initial Definitions

Three basic terms have been commonly used with respect to workers: blue-collar, white-collar, and knowledge. Beruvides and Sumanth (1987), in their initial study on defining these three types of work, developed the following definitions (table 2.1).

> Blue Collar Work is all work of a manual or physical nature whose output is clearly definable or tangible, and whose inputs are clearly definable and directly influential in the output produced with no discretion (or little, if any) permitted in the job task.

White Collar Work is all work of any nature whose output is composed mainly of tangible factors, with some intangible factors, and whose inputs are definable and directly influential in the output produced with little or no discretion in the job task.

Knowledge Work is all work of any nature whose output is composed of some tangible factors but is mainly of an intangible nature and whose inputs are not as clearly definable and can, but not necessarily have to, be influential in the output produced with substantially high discretion permitted in the job task.

Table 2.1: Characteristics of the different types of work.

(from Beruvides and Sumanth, 1987)

	Type of Work		
	Blue Collar	**White Collar**	**Knowledge**
Nature of Work	manual or physical	any nature	any nature
Output	clearly definable (tangible)	mainly tangible with some intangible factors	some intangible factors, but mainly intangible
Input	clearly definable and directly influential in output	definable and directly influential in output	not as clearly definable and can be, but not necessarily are influential in output
Degree of Discretion	practically none	little or none	very high

2.4.1.3 The Productivity Equation

There has been much work done by practitioners and researchers to measure white-collar productivity, (see Calmes, 1981, McGee and Welsh, 1982, Anthony, 1984, Mundel, 1978; Sink, 1985 and 1987, to mention a few). There are various measures of productivity: partial productivity, total factor-productivity, multi-factor productivity, and total productivity (Sumanth, 1979; Sink, 1985). The Total Productivity Model (TPM), developed by Sumanth (1979, 1984), defines total productivity as the ratio of the sum of total tangible outputs to the sum of the total tangible input, which is expressed mathematically as

$$TP = \frac{\Sigma O}{\Sigma_j \; I_j}$$

$$TP = \frac{\Sigma O}{I_H + I_M + I_C + I_E + I_X}$$

where O = total tangible output; I_H = human input; I_M = material input; I_C = capital input (including both working and fixed capital); I_E = energy input; I_X = other input expenses; and j = input factor.

2.4.1.4 The Infinitivity Problem

Beruvides and Sumanth (1987) use the Total Productivity Model to demonstrate the problems of measuring white-collar/knowldege work productivity using this traditional methodology. They first restructured the TPM equation as follows:

$$TP = \frac{\Sigma O}{I_H + I_T}$$

where $I_T = I_M + I_C + I_E + I_X$.

I_T, being the sum of the material, capital, energy, and other expense inputs, is seen as virtually negligible when compared to the human input (salary) in the case of knowledge work. The above equation was further transformed as

$$TP = \frac{\Sigma O}{I_H}(D_f)$$

where D_f is a constant multiplier termed the Departmental Factor of the form:

$D_f = I_H / (I_H + I_T)$.

This partitioning of the equation did not alter the equation and served to emphasize Beruvides and Sumanth's belief that knowledge work is mainly a function of human input. The equation was re-written as follows:

$$TP = \frac{\Sigma O}{I_H} \cdot \frac{I_H}{I_T} \cdot \frac{1}{(1+\frac{I_H}{I_T})}$$

$$TP = \frac{\Sigma O}{I_H} \cdot t \cdot \frac{1}{(1+t)}$$

where $t = \frac{I_H}{I_T}$ (called the 't-ratio')

The above equation was expressed in terms of t as:

$$TP = \frac{\Sigma O}{I_H} \; t\,(1 - t + t^2 - t^3 + \ldots) \text{ for all } 0 \leq t \leq 1$$

When t lies in the range of $0 \leq t \leq 1$, Beruvides and Sumanth believed this to be representative of blue-collar work and white-collar work. When t is greater than 1.0 ($t > 1$), that is, I_H is larger than I_T, they believe this is representative of most knowledge work. If in fact t is greater than 1.0, the above equation results in a negative value for total productivity (actually the above equation can not be used). This is impossible from a productivity standpoint because productivity can be zero or positive, but never negative (Sumanth 1984, 1979). The change in total productivity (ΔTP) can be a negative value, but not the level of productivity itself. So Beruvides and Sumanth express the equation for total productivity of knowledge work as:

$$TP_K = \frac{\Sigma O}{I_H} \cdot \frac{I_H}{I_H + I_T}$$

$$TP_K = \frac{\Sigma O}{I_H \left(1 + \frac{I_T}{I_H}\right)}$$

which can be approximated as

$$TP_K = \frac{\Sigma O}{I_H} \left(1 - t_k + t_k^2 - t_k^3 + \ldots\right) \text{ for } 0 \leq t_k \leq 1$$

where $t_k = \frac{I_T}{I_H}$ (called the 't_k-ratio')

The values of I_H, I_T, t, and D_f were then hypothetically calculated (table 2.2). The data were then graphed (figure 3.2). The graphical representation shows productivity for knowledge work approaching infinity. This clearly presents the problems with the traditional productivity measures for knowledge work, and emphasized the need to further define and clarify the definitions of work.

Table 2.2. Values of I_H, I_T, and t with respect to D_f.

(from Beruvides and Sumanth, 1987)

D_f	I_H	I_T	t
0	0	I_T	0
.25	I_H	$3I_T$	.33
.50	I_H	I_T	1.0
.75	I_H	$.33I_T$	3.0
.80	I_H	$.2I_T$	5.0
.91	I_H	$.1I_T$	10.0
.99	I_H	$.01I_T$	100.0
1.0	I_H	0	∞

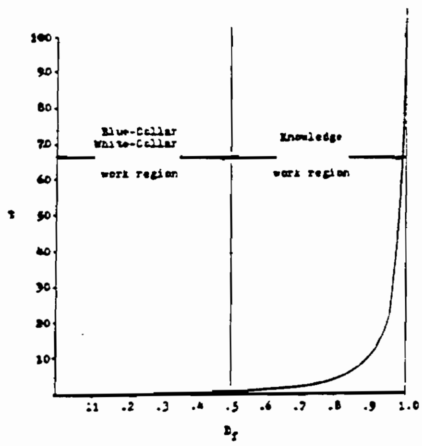

Figure 2.4. Graph of Tabulated Data on Df (from Beruvides and Sumanth, 1987)

2.4.2 THE UNIVERSE OF WORK CONCEPT

The need to further define work led Beruvides, Omachonu, and Sumanth (1988) to develop what they term the Universe of Work. The Universe of Work is a Venn diagram representation of the three types of work (blue-collar, white-collar, and knowledge work). Each type of work is represented by a separate circle, and all three (and their intersecting areas) comprise all of human work (figure 2.4). The emphasis of this diagram is to focus on work itself and not on the worker. That is, the authors' contention is that all workers, at some time in their work routine, may do any one of these three types of work (no matter their job position). The percent distribution of each type of work for specific positions is the defining characteristic of that particular job.

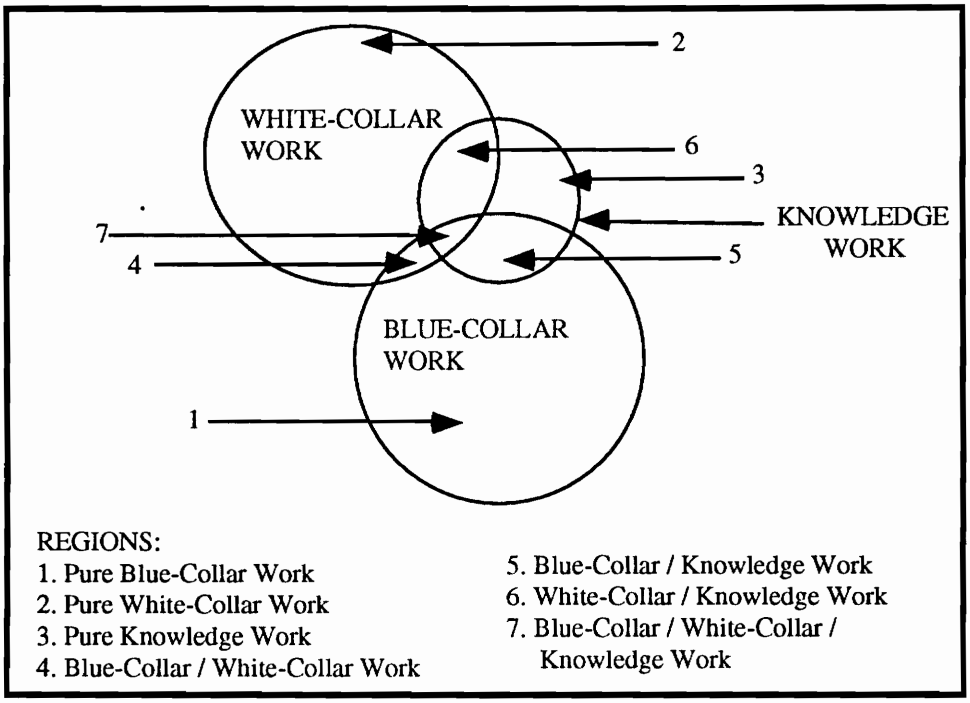

Figure 2.5. Schematic Representation of the Universe of Work (From Beruvides, Omachonu, and Sumanth, 1988).

2.4.2.1 A Conceptual Structure Using Set Theory

The Universe of Work (figure 2.5) is a pictorial representation of all conceivable human work. It is composed of three major subsets,: pure blue-collar, pure white-collar, and pure knowledge work. Beruvides, Omachonu, and Sumanth then speculated that there are at least seven distinct regions in which work can be categorized.

2.4.2.2 The Evolution of the Universe of Work

Beruvides, Omachonu, and Sumanth (1988) theorized that if the Universe of Work encompassed all of human work, the Universe is not necessarily stagnant or fixed. Thus, one would expect a change over time. The authors speculated that the Universe of

Work has evolved, in fact, as can be seen in figure 2.6. The authors go so far as to believe that the future will be predominantly knowledge work intensive.

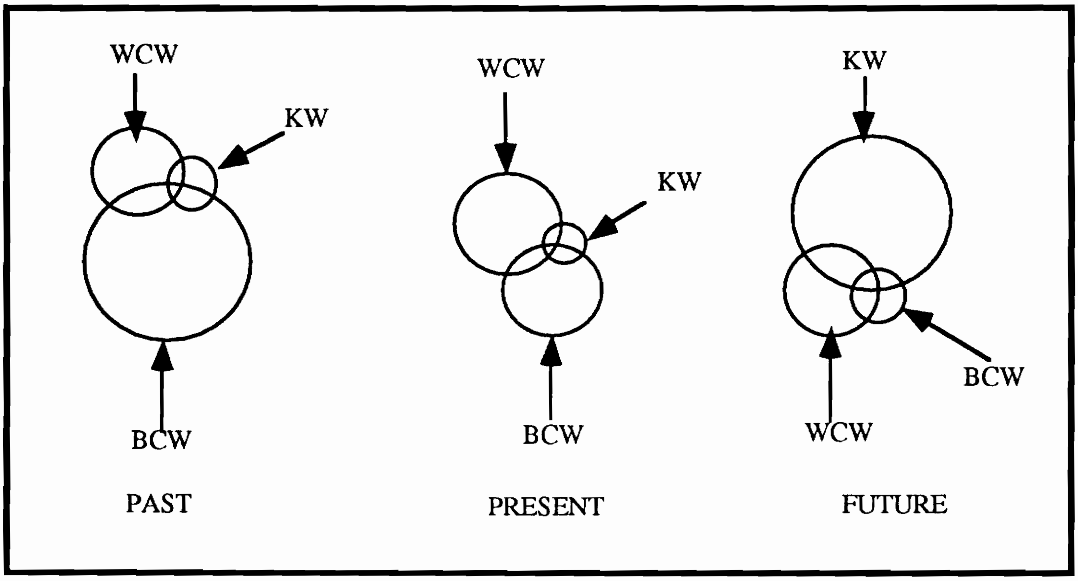

Figure 2.6. Evolution of the Universe of Work. (From Beruvides, Omachonu, and Sumanth, 1988)

2.4.3 THE MEASUREMENT -vs- IMPLEMENTATION DILEMMA

One of the major debates or questions within the work/productivity area is the measurement -vs- implementation dilemma. The problem lies in that implementation is often undertaken using weak or inappropriate measures. This was addressed by Sumanth, Omachonu, and Beruvides (1990) in their extensive review of the white-collar/knowledge work productivity literature. The results of their study revealed some very interesting points on work. This section reviews and analyzes the results of this extensive literature review.

2.4.3.1 A State-of-the-Art-Matrix (SAM) Review

The literature review by Sumanth, Omachonu, and Beruvides (1988) used computer data base techniques as well as standard library search techniques to obtain the bibliographic list of articles that served as the basis for the analysis. The articles spanned a time frame covering the 1960's through the 1980's.[18] The search revealed 120 articles and books on the subject matter. A SAM (State-of-the-Art-Matrix) technique was used to study the bibliographic list. The results are listed below in tables 2.3 - 2.10. We analyze these results in the next section (2.4.3.2).

[18] No substantive articles were found prior to 1960 on this subject matter.

Table 2.3. SAM Review (From Sumanth, Omachonu, and Beruvides, 1988).

AUTHORS	YEAR	Measurement	Improvement	Definitional	Opinion Based
1. Broadwell	1965	√		√	
2. Hulbert & Scalera	1967	√			
3. Heller	1969				√
4. Goodman et. al.	1970	√			
5. Hill	1970	√			√
6. Vincent & Mirakhor	1972	√	√	√	
7. Doering	1973	√			
8.Martin	1977	√	√		
9.Mazzola & Kauffman	1978	√	√		
10. Mundel	1978	√	√	√	√
11. Cannan	1979	√	√		
12. Stahl et. al.	1979	√			
13. Fisher & McLaughlin	1980	√	√		
14. Nagaprasanna	1980		√		
15. Baumgardner	1981	√	√		
16. Finley	1981		√		
17. Grahn	1981		√		
18. Metzger	1981				√
19. Rowe	1981	√			
20. Curley & Pyburn	1982			√	

Table 2.3. SAM Review (Continued).

AUTHORS	YEAR	Measurement	Improvement	Definitional	Opinion Based
21. Douglas	1982	√			
22. Edelman	1982	√	√		
23. Gery	1982			√	√
24. Jones	1982				√
25. Keller & Holland	1982	√			
26. Kish	1982	√	√		
27. Metzger	1982				√
28. Meyer	1982	√	√	√	
29. Rockhold	1982			√	√
30. Ruch	1982	√			
31. Slaughter	1982		√		
32. Stewart & Calloway	1982	√	√		
33. Suhorsky	1982		√		
34. Ullmann	1982			√	√
35. Robinson	1983	√			
36. Bolte	1983	√	√	√	
37. Brisley & Fielder	1983	√	√		
38. Dougherty	1983				√
39. Goldfield	1983		√		
40. Goldstein	1983		√	√	

Table 2.3. SAM Review (Continued).

AUTHORS	YEAR	Measurement	Improvement	Definitional	Opinion Based
41. Hoop & Walzansky	1983	√		√	
42. Hudson	1983				√
43. Kristakis	1983		√		
44. Lambert	1983		√		
45. Maas	1983				√
46. Olson	1983		√		√
47. Packer	1983				√
48. Rosenberg	1983	√	√		
49. Soncini	1983	√	√		
50. Staff Report (1)	1983				√
51. Staff Report (2)	1983		√		
52. Staff Report (3)	1983				√
53. Steinbrecker	1983				√
54. Thamhain	1983				√
55. Weick	1983				√
56. Witting	1983				√
57. Wolfe & Vandle	1983			√	√
58. Anthony	1984	√			
59. Ashkenas & Schaffer	1984		√		√
60. BAI/APC	1984	√			

Table 2.3. SAM Review (Continued).

AUTHORS	YEAR	Measurement	Improvement	Definitional	Opinion Based
61. Bancroft et. al.	1984		√		
62. Bolte	1984	√	√		
63. Brown	1984		√		
64. Buckwater	1984		√		√
65. Christopher	1984	√	√		
66. Conn	1984		√	√	
67. Dickinson	1984	√		√	
68. Filley	1984		√		
69. Frazelle & Smith	1984		√		
70. Greenwood	1984		√	√	√
71. Heshizer & Graham	1984				√
72. Higgins & Dice	1984		√		
73. Hoffman & Hobson	1984		√		
74. Inmon	1984	√		√	
75. Iseberg	1984	√			
76. Jacobs	1984		√		√
77. Jenkins	1984		√		
78. Kuzela	1984		√		
79. Liker & Hancock	1984		√		
80. Major	1984		√		

Table 2.3. SAM Review (Continued).

AUTHORS	YEAR	Measurement	Improvement	Definitional	Opinion Based
81. Miller	1984	√		√	
82. Porter	1984	√			
83. Quinn	1984		√		
84. Ranftl	1984	√	√	√	
85. Richards	1984		√	√	√
86. Root	1984				√
87. Sink et. al.	1984	√		√	
88. Smith, C.	1984	√	√		
89. Smith, C. T.	1984		√		
90. Staff Report (4)	1984				√
91. Stahl et. al.	1984	√			
92. Staples	1984		√		√
93. Sutton	1984		√		
94. Swain & Sink	1984	√		√	
95. Zoch & Weiner	1984		√		
96. Bocazany	1985		√		√
97. Camp	1985		√		
98. Cerveny & Sanders	1985		V		
99. Daniels	1985		V		
100. Danzinger & Kraemer	1985		√		

Table 2.3. SAM Review (Continued).

AUTHORS	YEAR	Measurement	Improvement	Definitional	Opinion Based
101. Drummond	1985	√	√		
102. Frazelle & Smith	1985		√		
103. Golberg	1985		√		
104. Larson & Fielden	1985				√
105. Olsen	1985	√	√		
106 Sink	1985		√		
107. Staff Report (5)	1985		√		
108. Staples	1985		√	√	√
109. Thurow	1985				√
110. Tutle & Romanowski	1985	√		√	
111. Bowen	1986				√
112. Fitz-Enz (1)	1986		V		
113. Fitz-Enz (2)	1986		√		
114. Greenberg	1986	√			
115. Hamann	1986	√	√		
116. Schroeder et. al.	1986	√			
117. Semich	1986				√
118. Staff Report (6)	1986				√
119. Staff Report (7)	1986				√
120. Thurow	1986				√

Table 2.3. SAM Review (Continued).

AUTHORS	YEAR	Measurement	Improvement	Definitional	Opinion Based
121. Beruvides & Sumanth	1987	√		√	√
122.Kuzela	1989				√
123. Beruvides, Omachonu, Sumanth	1989	√		√	
124. Omachonu & Beruvides	1989	√			

Table 2.4. SAM Review for Articles on Measurement.

(From Sumanth, Omachonu, and Beruvides, 1988).

AUTHORS	YEAR	Model	Descriptive
1. Broadwell	1965		√
2. Hulbert & Scalera	1967	√	
3. Goodman et. al.	1970	√	
4. Hill	1970		√
5. Vincent & Mirakhor	1972	√	
6. Doering	1973	√	
7. Martin	1977	√	
8. Mazzola & Kauffman	1978	√	
9. Mundel	1978	√	
10. Cannan	1979	√	
11. Stahl & McNichols	1979		√
12. Fischer & McLaughlin	1980		√
13. Baumgardner	1981	√	
14. Grahn	1981		√
15. Rowe	1981	√	
16. Edelman	1982		√
17. Douglas	1982		√
18. Keller & Holland	1982	√	
19. Kish	1982	√	
20. Meyer	1982		√

Table 2.4. SAM Review for Articles on Measurement (Continued).

AUTHORS	YEAR	Model	Descriptive
21. Robinson	1982	√	√
22. Ruch	1982	√	√
23. Stewart & Calloway	1982		√
24. Suhorsky	1982		√
25. Bolte	1983	√	
26. Brisley & Fielder	1983		√
27. Goldfield	1983		√
28. Hoop & Walzansky	1983		√
29. Lehrer	1983	√	√
30. Olson	1983		√
31. Soncini	1983	√	
32. Rosenberg	1983	√	
33. Anthony	1984	√	
34. BAI/APC	1984	√	√
35. Bancroft et. al.	1984		√
36. Bolte	1984		√
37. Brown	1984	√	√
38. Buckwalter	1984		√
39. Christopher	1984	√	√
40. Conn	1984		√

Table 2.4. SAM Review for Articles on Measurement (Continued).

AUTHORS	YEAR	Model	Descriptive
41. Dickinson	1984		√
42. Filley	1984		√
43. Frazelle & Smith	1984		√
44. Heshizer & Graham	1984		√
45. Higgins & Dice	1984	√	√
46. Hoffman & Hobson	1984		√
47. Inmon	1984		√
48. Iseberg	1984	√	
49. Jacobs	1984		√
50. Jenkins	1984		√
51. Liker & Hancock	1984		√
52. Major	1984		√
53. Miller	1984	√	√
54. Porter	1984		√
55. Quinn	1984		√
56. Ranftl	1984		√
57. Richards	1984		√
58. Sink et. al.	1984	√	√
59. Smith, C.	1984		√
60. Smith C. T.	1984		√

Table 2.4. SAM Review for Articles on Measurement (Continued).

AUTHORS	YEAR	Model	Descriptive
61. Stahlet. al	1984	√	
62. Staples	1984		√
63. Sutton	1984		√
64. Swain & Sink	1984	√	
65. Zoch & Weiner	1984		√
66. Cerveny & Sanders	1985		√
67. Camp	1985		√
68. Daniels	1985		√
69. Danzinger & Kraemer	1985		√
70. Drummond	1985		√
71. Frazelle & Smith	1985		√
72. Golberg	1985		√
73. Olsen	1985		√
74. Sink	1985		√
75. Tutle & Romanowski	1985	√	√
76. Greenberg	1986		√
77. Hamann	1986		√
78. Schroeder et. al.	1986		√
79. Beruvides & Sumanth	1987	√	√
80. Beruvides, Omaconu, & Sumanth	1989		√
81. Omachonu & Beruvides	1989	√	√

Table 2.5. SAM Review for Articles on Improvement.

(From Sumanth, Omachonu, and Beruvides, 1988).

AUTHORS	YEAR	TECHNIQUE Incentive Based	Motivation Concepts	Systemized Approach	Empirical Approach
1. Vincent & Mirakhor	1972	√	√		
2. Martin	1977			√	√
3. Mazzola & Kauffman	1978			√	√
4. Munde	1978			√	√
5. Cannan	1979			√	
6. Fischer & McLaughlin	1980		√		√
7. Nagaprasanna	1980	√	√		√
8. Baumgardner	1981		√	√	
9. Finley	1981			√	√
10. Grahn	1981			√	
11. Rowe	1981				√
12. Douglas	1982		√		
13. Edelman	1982			√	√
14. Kish	1982			√	
15. Meyer	1982			√	
16. Slaughter	1982			√	
17. Stewart & Calloway	1982		√		
18. Suhorsky	1982		√		√
19. Bolte	1983			√	√
20. Brisley & Fielder	1983			√	√

Table 2.5. SAM Review for Articles on Improvement (Continued).

AUTHORS	YEAR	TECHNIQUE Incentive Based	 Motivation Concepts	Systemized Approach	Empirical Approach
21. Goldfield	1983		√		
22. Goldstein	1983			√	
23. Kristakis	1983			√	
24. Lambert	1983		√	√	√
25. Lehrer	1983			√	
26. Olsen	1983			√	
27. Rosenberg	1983			√	√
28. Soncini	1983				
29. Staff Report	1983			√	
30. Ashkenas & Schaffer	1984			√	
31. BAI/APC	1984				√
32. Bancroft et. al.	1984			√	√
33. Bolte	1984			√	
34. Brown	1984				√
35. Buckwalter	1984				√
36. Christopher	1984			√	√
37. Conn	1984		√	√	
38. Dickinson	1984				√
39. Filley	1984			√	
40. Frazelle & Smith	1984			√	√

Table 2.5. SAM Review for Articles on Improvement (Continued).

AUTHORS	YEAR	TECHNIQUE			
		Incentive Based	**Motivation Concepts**	**Systemized Approach**	**Empirical Approach**
41. Greenwood	1984			√	√
42. Goldberg & Shenhav	1984				√
43. Higgins & Dice	1984			√	√
44. Hoffman & Hobson	1984	√	√		√
45. Inmon	1984				√
46. Isenberg	1984				√
47. Jacobs	1984		√	√	√
48. Jenkins	1984				√
49. Kuzela	1984			√	
50. Liker & Hancock	1984		√	√	
51. Major	1984			√	√
52. Miller	1984			√	√
53. Porter	1984				√
54. Quinn	1984			√	√
55. Ranftl	1984		√	√	√
56. Sink et. al.	1984			√	√
57. Smith, C. 1984	1984			√	
58. Smith, C. T.	1984	√	√		
59. Staples	1984			√	
60. Sutton	1984		√	√	√

Table 2.5. SAM Review for Articles on Improvement (Continued).

AUTHORS	YEAR	TECHNIQUE			
		Incentive Based	**Motivation Concepts**	**Systemized Approach**	**Empirical Approach**
61. Swain & Sink	1984			√	√
62. Zoch & Weiner	1984				√
63. Bocazany	1985		√		
64. Camp	1985	√	√	√	√
65. Cerveny & Sanders	1985		√		
66. Daniels	1985		√		√
67. Danzinger & Kraemer	1985			√	
68. Drummond	1985			√	√
69. Frazelle & Smith	1985		√		
70. Goldberg	1985				√
71. Olsen	1985		√		
72. Olsen (2)	1985		V		
73. Sink	1985			√	
74. Staff Report	1985			√	√
75. Staples	1985			√	
76. Tuttle & Romanowski	1985			√	√
77. Frazelle & Smith	1986				√
78. Fitz-Enz	1986		√		
79. Fitz-Enz	1986		√		
80. Hamann	1986				√

Table 2.6. Articles Dealing with Productivity Measures.

(From Sumanth, Omachonu, and Beruvides, 1988).

	Number of Articles				
	1960s	**1970s**	**1980s**	**Total**	**%**
Models	1	6	13	20	29
Descriptive	1	2	37	40	57
Models & Descriptive	0	1	9	10	14
Total	2	9	59	70	

Table 2.7. Articles Dealing with Productivity Improvement.

(From Sumanth, Omachonu, and Beruvides, 1988).

	Number of Articles				
	1960s	**1970s**	**1980s**	**Total**	**%**
Systemized Approach	0	1	17	18	30
Tested Methodology (Empirical)	0	0	14	14	24
Both Methodology and Empirical Evidence	0	3	24	27	46
Total	0	4	55	59	

Table 2.8. Breakdown by Major Areas of Concern.

(From Sumanth, Omachonu, and Beruvides, 1988).

	1960s	1970s	1980s	Total	%
Definitions (D)	_	_	3	3	3
Measurement (M)	1	3	10	14	11
Improvement (I)	_	_	32	32	24
Opinion-based (O)	1	_	24	25	19
Combinations of D, M, I, & O	1	6	48	55	42
All Four facets	_	1	2	3	2

Note: Combinations by percentage are as follows: M + I = 17.7%; M + D = 7.3%; M + O = 2.1%; I + D = 3%; I + O = 5.2%; D + O = 4.2%; M + I + D = 4.2%; all other combinations equal zero%.

Table 2.9. Stated Fields of Study.

(From Sumanth, Omachonu, and Beruvides, 1988).

	1960s	1970s	1980s	Total	%
1. Banking	--	--	6	6	4
2. Clerical/secretarial	_	1	3	4	3
3. Data or word Processing	_	_	3	3	2
4. Engineers	1	1	3	5	4
5. Ergonomics	_	_	3	3	2
6. Hospitals	_	1	1	2	2
7. Information systems	_	_	1	1	1
8. Intellectual technology	_	_	1	1	1
9.Knowledge worker	_	_	2	2	2
10. Manager/executive	_	_	14	14	11
11. Office	_	1	12	13	10
12. Office automation	_	_	13	13	10
13. Organizational	_	_	1	1	1
14. Performance appraisal	_	_	1	1	1
15. Professional	_	_	2	2	2
16. Programmers	_	_	2	2	2
17. R&D	1	_	4	5	4
18. Scientist	_	4	2	6	4
19. Service	_	1	3	4	3
20. White collar	_	_	40	40	31
Totals	2	9	117	128	100

Table 2.10. Key Word Listing (From Sumanth, Omachonu, and Beruvides, 1988).

Serial	Keyword	Frequency of use	Serial	Keyword	Frequency of use
1	Ability	2	21	Innovation	4
2	Attitude	3	22	Intellectual technology	2
3	Automation	4	23	Intuition	1
4	Commitment	2	24	Involvement	3
5	Communications	11	25	Job enrichment	1
6	Cooperation	1	26	Job redesign	1
7	Coordination	1	27	Job security	2
8	Creativity	8	28	Judgment	1
9	Decision making	8	29	Knowledge	7
10	Delegation	1	30	Leadership	1
11	Discretion	2	31	Methods	1
12	Effectiveness	5	32	Monitoring	2
13	Efficiency	12	33	Motivation	15
14	Effort	1	34	Non-repetitive work	4
15	Environment	2	35	Office automation	26
16	Flexibility	2	36	Organizational devpt	2
17	Functions	5	37	Organizational expect.	1
18	Ideas	2	38	Organizational liaison	2
19	Incentive	4	39	Outcome	4
20	Information system	13	40	Outputs	1

Table 2.10. Key Word Listing (Continued).

Serial	Keyword	Frequency of use	Serial	Keyword	Frequency of use
41	Participation	14	53	Responsibility	2
42	Performance	9	54	Rote perception	1
43	Physical Fitness	1	55	Satisfaction	6
44	Planning	4	56	Self esteem	1
45	Price recovery	2	57	Skill	2
46	Problem solving	1	58	Supervision	1
47	Procedures	2	59	Technology	10
48	Profitability	5	60	Time management	1
49	Quality	11	61	Training	5
50	Quality circles	2	62	Work environment	5
51	Recognition	5	63	Work objectives	2
52	Research & development	1	64	Work space design	1

2.4.3.2 The Need for Further Definition

The SAM review by Sumanth, Omachonu, and Beruvides (1988) revealed some major trends. The early works (1960's and early 1970's) emphasized defining work. These efforts soon gave way to customized designs geared for direct implementation. Table 2.3 shows the large number of implementation studies as compared to definitional studies. Table 2.4 looks at just those articles that stressed measurement and found an emphasis on descriptive studies and a deficiency in model building. In fact, no comprehensive work model was evident. Tables 2.5-2.10 are an in-depth content analysis of the 124 articles looking at such things as the types of implementation programs, key word analysis, etc. The overwhelming result of the search was the lack of definitions of work itself. Sumanth, Omachonu, and Beruvides (1989) state "to improve any system or process, it is important, first, to be able to measure the system by quantifying the values involved. Even before that, it is essential to define what has to be measured" (p. 341). There exists a real research need to define and verify the definitions of work.

2.5 THE B/W/K WORK MODEL

"The technological future is inevitable. However, the successful introduction, adoption, implementation, and maintenance of advanced technology heavily depends on the people who are part of this revolution," (Ozatalay and Reilly, 1990, p. 749). Ozatalay and Reilly here touch upon one of the more critical points in management in general, and management of technology specifically; human resource management. This section continues to look at work and the definition of work by first looking at a business or management perspective. Specifically, the Management System Model (Kurstedt, 1990 a and b) is analyzed. Then, the B/W/K work model (Beruvides and Koelling, 1991) is presented, which is an expansion of the initial definitions presented by Beruvides and Sumanth (1987), incorporating some management/business concepts from the Management System Model.

2.5.1 A MANAGEMENT PERSPECTIVE

Having looked at work from physical, human factors, philosophical, industrial, economic, and psychological perspectives, it is apparent that a managerial perspective is necessary to complete this analysis. Beruvides and Koelling (1991) extended the research presented above on work by incorporating some of the work done by Kurstedt (1990 a and b) in his Management System Model.

2.5.1.1 The Management System Model

Kurstedt (1990a and b) developed the Management System Model in the 1980's (figure 2.7). Kurstedt (1990a) believes every worker has a 'domain of responsibility' (the equipment, personnel, inventory, work tasks, job assignments, etc. required to accomplish his/her work task) and classified four 'frameworks' to contextualize this domain (figures 2.8). The frameworks model the different levels of uncertainty, comprehensiveness, structure, and maturity of a worker's domain of responsibility.[19] Kurstedt also terms these frameworks as the levels of endeavor.

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[19] The four frameworks are not solely the development of Kurstedt. The framework for pursuits (level of uncertainty) is Kurstedt's conception. The three remaining frameworks are based on the work of Ackoff, (1967), Anthony, (1965), Forrester, (1961), Gorry and Scott Morton, (1971), MacIntosh, (1981), Mintzberg, (1980), and Petersen, (1977).

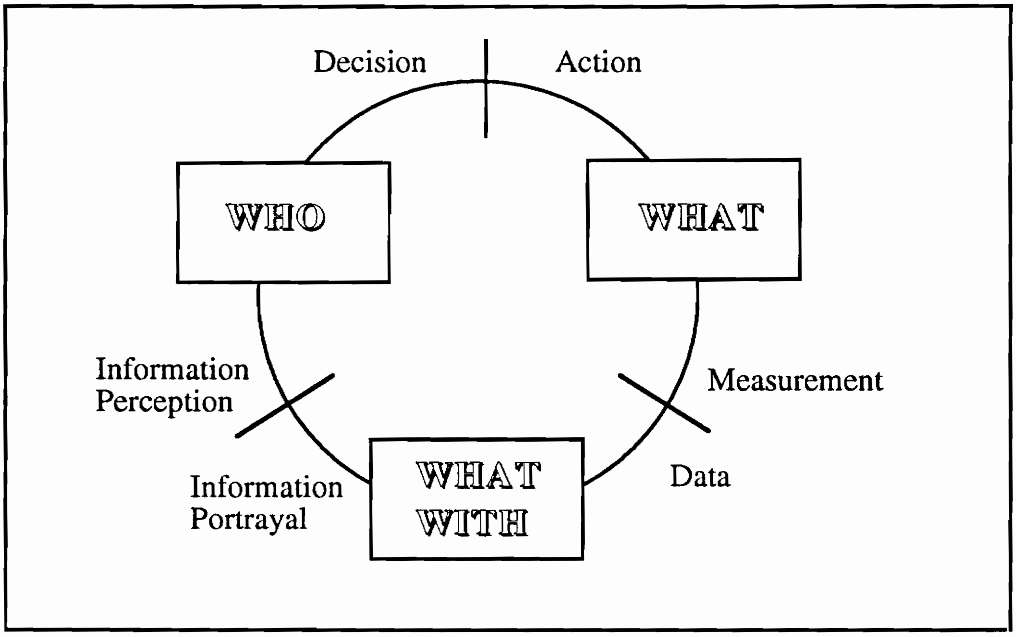

Figure 2.7 The Management System Model (Kurstedt, 1990a).

2.5.1.2 The Levels of Endeavor

A further development to the Universe of Work (section 2.4.2) is the result of blending the material presented thus far with the four frameworks of Kurstedt's Management System Model (1990a and 1990b). [Note: Kurstedt uses the frameworks to describe a manager's domain of responsibility. Kurstedt does not use the frameworks to define work as presented here].

2.5.2 WORK REDEFINED

By incorporating the four frameworks in to the work definitions previously presented (section 2.4.1.2), Beruvides and Koelling (1991) further expanded the definitions of work. The terms blue-collar, white-collar, and knowledge work were replaced with B, W, and K to avoid the value-laden connotations associated with the terms. The revised definitions are as follows. Table 2.11 has a listing of the eight work characteristics of the revised definitions.

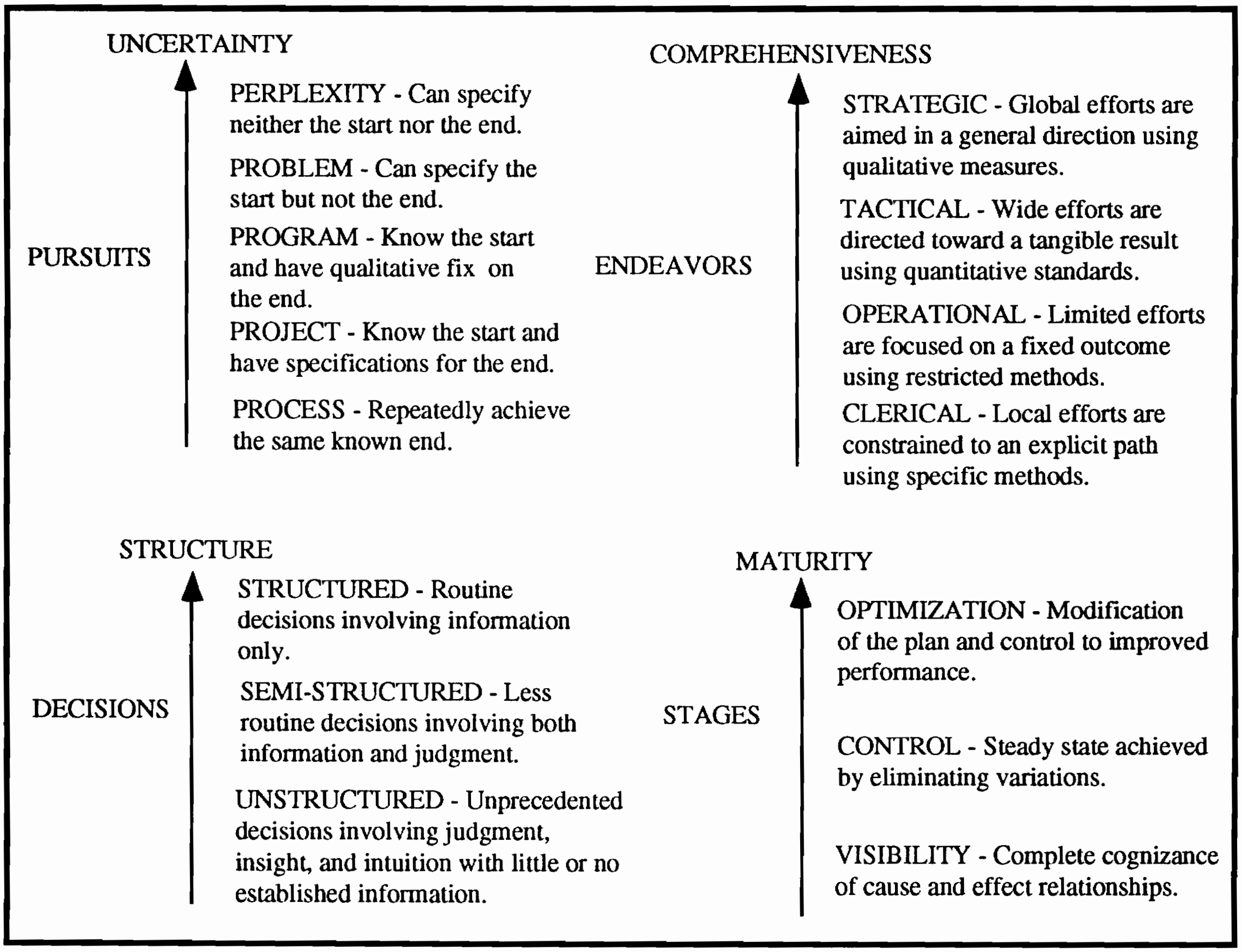

Figure 2.8. Frameworks from Kurstedt's (1990a) Management System Model.

B - Work is all work of a manual or physical nature whose output is clearly definable or tangible, and whose inputs are clearly definable and directly influential in the output produced with no discretion (or little) permitted in the job task. Job task pursuits and tool use needs can best be described as process and project levels on the uncertainty scale; endeavors are functional[20] and operational; decisions are structured; and stages of maturity can be described in the visibility to control level.

W - Work is all work of any nature whose output is composed mainly of tangible factors with some intangible factors, and whose inputs are definable and directly influential in the output produced, with little or no discretion in the job task. Job task pursuits and tool use needs can best be described as process, project and program levels on the uncertainty scale; endeavors are operational to tactical; decisions are structured as well as semi-structured; and stages of maturity can be described in the visibility to control level.

K - Work is all work of any nature whose output is composed of some tangible factors but is mainly of an intangible nature, and whose inputs are not as clearly definable and may be influential in the output produced, with substantially high discretion permitted in the job task. Job task pursuits and tool use needs can best be described as program, problem, and perplexity levels on the uncertainty scale; endeavors are tactical and strategic; decisions are mainly semi-structured to unstructured; and stages of maturity can be described in the control to optimization level.

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20 The definition of B-work has been modified (see the work of Yarbrough, Koelling, and Beruvides (1992)). The original definition used to read 'clerical and operational,' and was modified to 'functional and operational,' so as to reflect a more correct depiction of B-work.

Table 2.11. Characteristics for the Three Types of Work.

(Adapted from Beruvides and Koelling, 1992a)

	Type of Work		
	B Work	W Work	K Work
Nature of Work	manual or physical	any nature	any nature
Outputs	clearly definable (tangible)	mainly tangible with some intangible factors	some tangible factors, but mainly intangible
Inputs	clearly definable and directly influential in output	definable and directly influential in output	not as clearly definable and can be, but not necessarily are influential in output
Degree of Discretion	practically none	little or none	very high
Pursuit Level	process and project level	process, project, and program level	program, problem and perplexity level
Level of Endeavor	clerical and operational	clerical to tactical	tactical and strategic
Decision Structure	structured	structured and semistructured	semi-structured to unstructured
Stage of Maturity	visibility to control level	visibility to control level	control to optimization level

Expanded characteristics of work

2.5.3 THE WORK PATH CONCEPT [21]

To further understand work one needs to look at the tools of work. Beruvides and Koelling (1992b) do this by developing the concept of the work path. The idea is that there is a work path to all work. This is a sequence comprised of a purpose, an objective, a methodology, a goal, a method, a technique, and ultimately a tool or tools to implement an action (figure 2.9). The work path is further explained as follows:

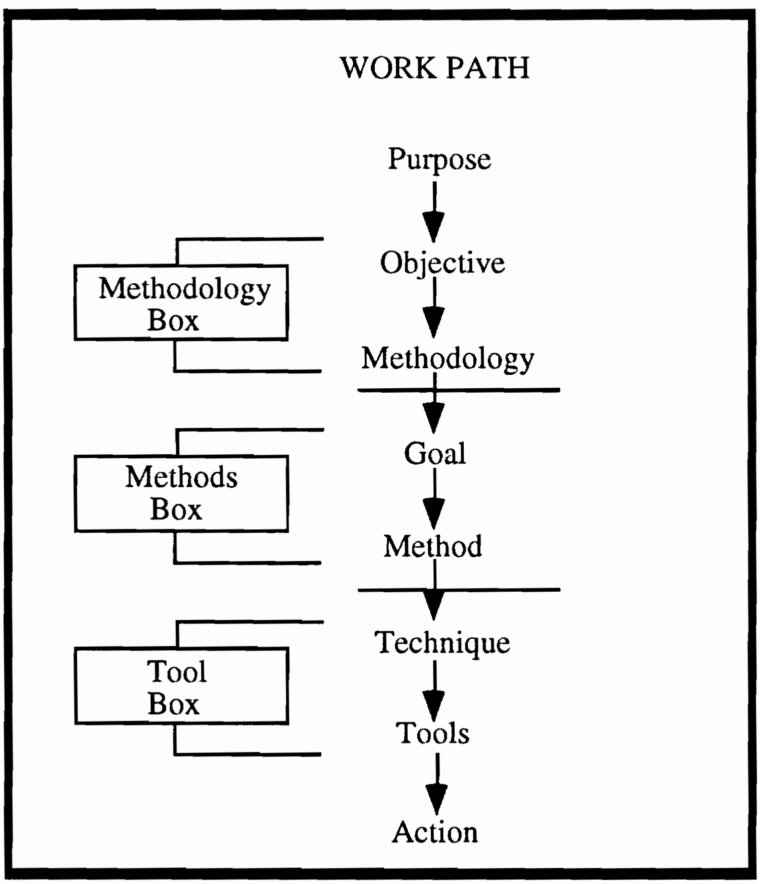

Figure 2.9. The Work Path Concept (Beruvides and Koelling, 1992b).

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[21] This section draws heavily on the work of Beruvides and Koelling (1992b).

> For example, an individual may have the purpose of building a living environment to shelter him or herself from the elements. There are many different possible objectives that could fulfill this purpose, but let's say the individual decides to build a house. Thus, a methodology must be devised to accomplish this. This again has many possible options. Let's assume this individual is knowledgeable in the construction techniques of wood house building. Goals must be devised to carry out the specific methodology. Amongst the myriad of goals needed to accomplish this task, one specific goal is to join two pieces of wood. There are again a wide variety of methods to do this (i.e.. gluing, tying, mechanical, etc.). Let's say the individual decides to use a mechanical method (such as joining the wood pieces in a mechanical way). Then, no doubt, a technique must be chosen to do this (hammering or some form of stapling as in the use of a staple gun). The method influences the tool and action to accomplish the task. So we see that tools are linked to a specific work path (Beruvides and Koelling, 1992 b; p.4).

The authors then link the work path to the definitions of work via the frameworks (figure 2.10). The figure shows that the purpose, objective, and methodology of a work path are in the domain of K-work. The goals and methods are part of W-work. And the techniques and actions are in the domain of B-work. Tools can be of a physical or mental nature in this framework (with most having representation in both the physical and mental state). There are tools for all three types of work (B/W/K), with the tools being classified into three groups, so that B-work requires a 'tool box,' W-work a 'methods box,' and K-work a 'methodology box' (figure 2.9).

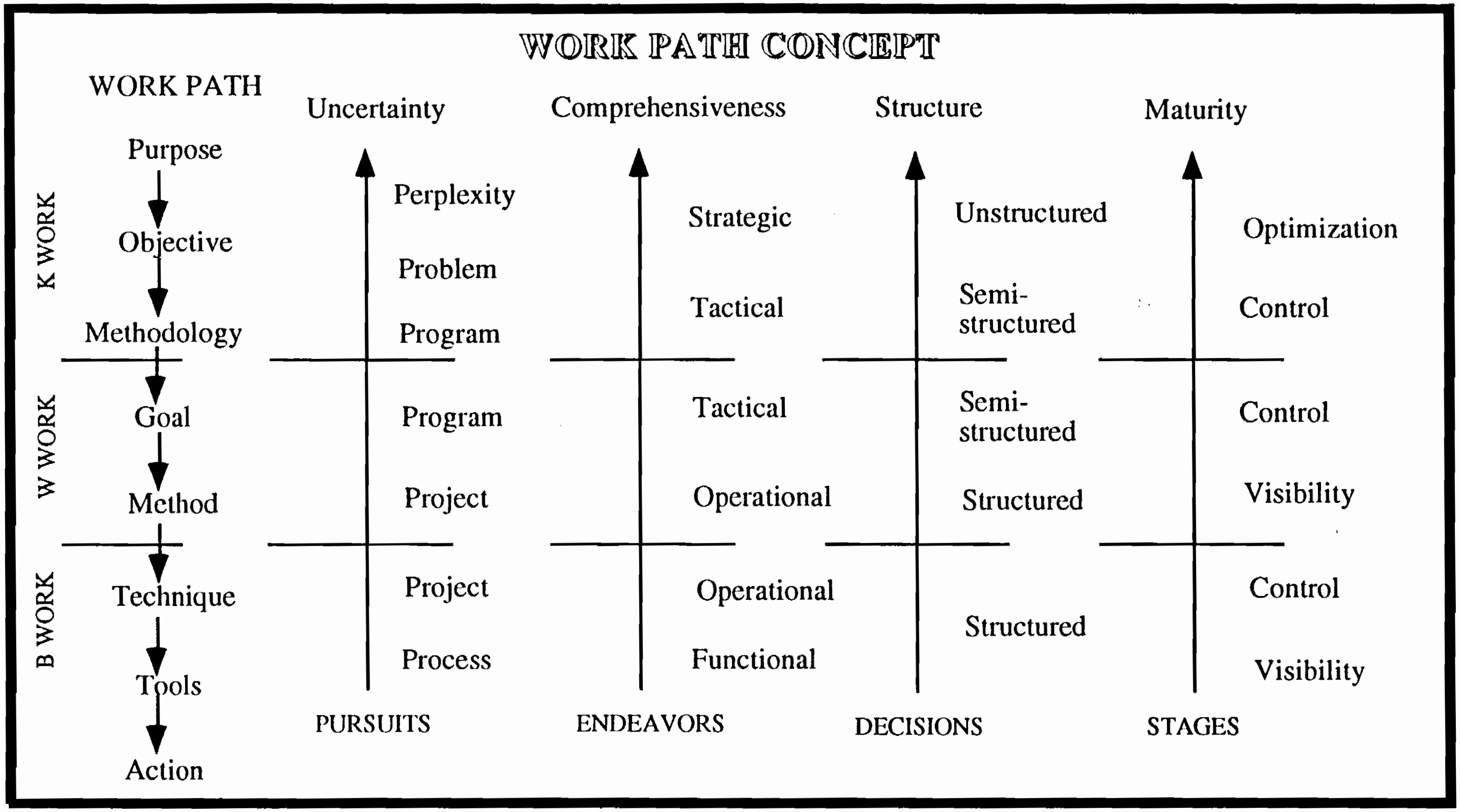

Figure 2.10. The Work Path Concept Model.

2.5.4 WORK AND TOOLS

Classifying tools can be done in a myriad of ways. From the previous section we see that tools can be placed in the context of the work path and are defining elements in the type of work being addressed. Mapping tools for B-work is not viewed as critical as it is for W and K-work. This is because of the usually close relationship between B-work tasks and the tools used. The complexity of the tasks involved, especially in K-work, can cloud the optimality of the tools to be used. To address this problem, Beruvides and Koelling (1992b) suggest the use of technology space maps. Technology space maps are simply two dimensional grids or matrices where critical dimensions (such as system life cycle and system hierarchy) are arranged as the rows and columns of the matrix (deWet, 1992). This matrix is then used to map an organization's technological abilities to manage the organization's technology strategies.

In a similar vein, Beruvides and Koelling use deWet's (1992) technology mapping technique to map a worker's job tasks, services, and/or products provided clients or customers. This allows an analyst or IE to map a worker's potential work tasks and responsibilities (what we'd like done). Morris (1979) created a matrix for industrial engineering work for dealing with clients (called the professional mode - client change matrix). Beruvides and Koelling (1992b) adapted Morris's matrix to reflect the tool mapping conception (figure 2.11). This mapping technique could be used to determine such things as worker or position tool technology competence, training requirements, job enrichment, or job redesign.

TOOL MAPPING DIAGRAM

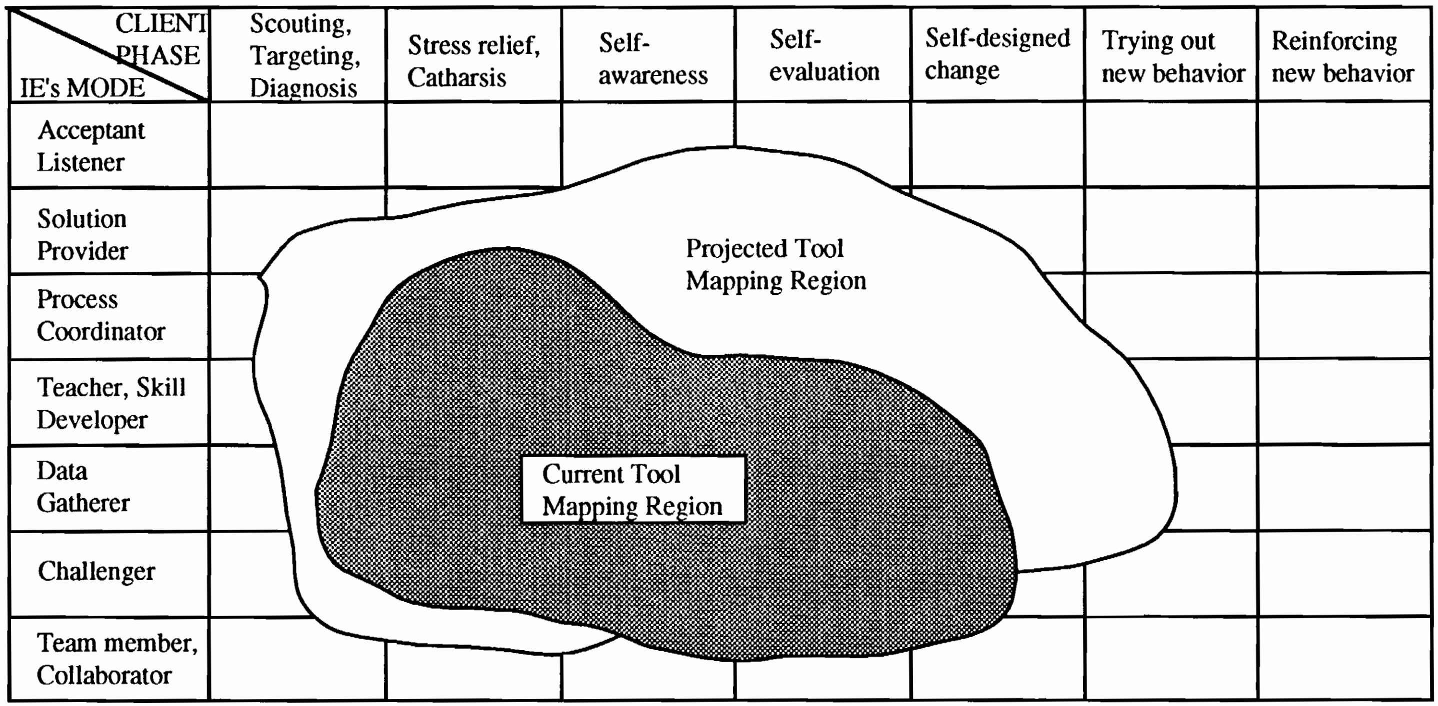

Figure 2.11 Technology Space Mapping Concept used for Mapping Tools (From Beruvides and Koelling, 1992b).

2.6 METHODS OF RESEARCHING WORK

There are several methodologies with which to analyze work and work tasks. Time and motion studies are commonly known methods for analyzing work. These methodologies make up part of the arsenal of techniques used in scientific management. (Taylor, 1911 and 1903; Gilbreth, 1914 and 1911). This methodology, although very useful for analyzing mainly-B type work, is inappropriate for mainly-W and K type work. Work sampling (Niebel, 1988 and Barnes, 1980) is another method for investigating work that is better suited for the W and K type work environments. Other methodologies used for these types of work are the use of diaries (Kurke and Aldrich, 1983), observational methods (Guest, 1956; Ponder, 1957), questionnaires (Allen, 1981), and structured observation (Mintzberg, 1973, 1975; Shapira and Dunbar, 1980; and Kurke and Aldrich, 1983).

Each method has its strengths and weaknesses. Time and motion studies are useful for highly structured work. Work sampling is a better method for less structured work environments. This method also requires less effort and expense than the traditional methods because a random sampling technique is used. The use of diaries is convenient and less intrusive than most methods, but data can be missing, and not as representative, since data are not recorded at the time the task is being accomplished. Questionnaires are another useful tool, but also do not record data as they occur. The observation method is a format that records data at the time they occur, but is prone to researcher bias. Structured observation helps overcome this by structuring the observation technique to limit observer bias. There is no one best method. The objective is to determine which method will best fit the researcher's need (soundness of data, observation of work, ease of data recording, cost, time, etc.).

2.7 RESEARCH INFERENCE TREE FOR WORK

This chapter presented work from many different angles. The need for a more complete definition of work has been noted in the analysis of the literature. The B/W/K work model is an attempt to address the definitional deficiency that exists for the concept of work from an industrial point of view. Work is an important area of research both for society as a whole and industrial engineering in particular. Work is a relevant and necessary research endeavor for the field of industrial engineering. To this end a research agenda (plan) is presented. To build a research program to study work, one undoubtedly needs a model on which to base the effort. This research program will rely on the B/W/K work model described above. There are many facets of the B/W/K work model that need investigation (soundness of definitions, validation of the work path conception, etc.). Figure 2.12 is an inference tree for research into work, where each of the major branches is envisioned as a research effort. Thus, figure 2.12 lays out a 5 to 10 year research agenda to aggressively attack the study of work. It is of importance to note that the 'Work Research Program Tree' is based on a western civilization conception of work. It may be of interest in the future, once this program has exhausted many of the inferences depicted in figure 2.12, to analyze the concept of work in other cultures.

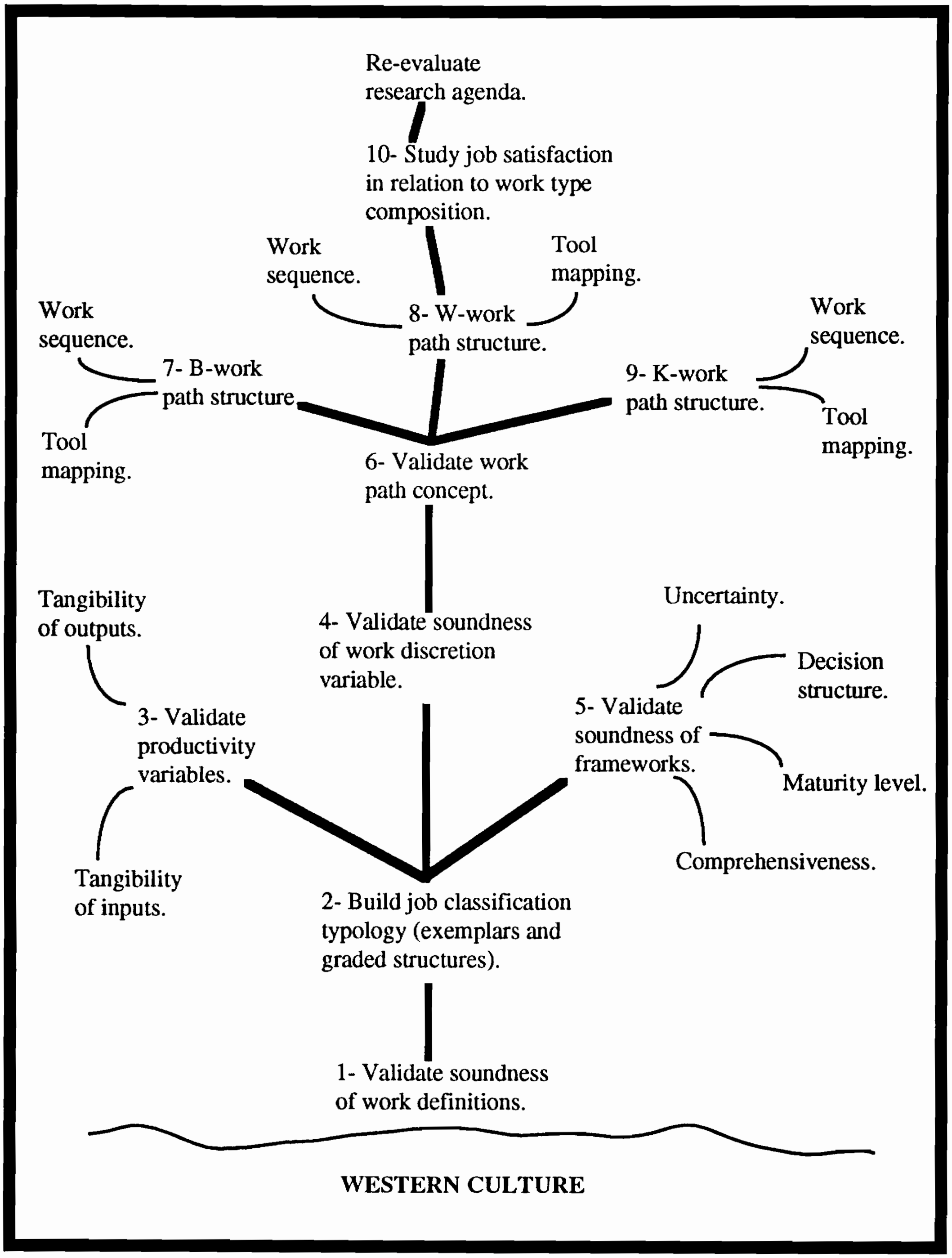

Figure 2.12 Work Program Research Tree.

2.8 RESEARCH IMPLICATIONS

Taking the research agenda presented in section 2.6, it is evident that the first step in addressing work research using the B/W/K paradigm is to conduct a confirmatory study to determine the soundness of the B/W/K work model's operational properties. This is in fact what this research has addressed. The methodology given in the next chapter (3) is a specific and detailed research effort to accomplish the first step of the research agenda (inference tree) described above. In fact, this specific research effort is the initiating step in the research effort of the inference tree on the study of work.

CHAPTER 3

RESEARCH METHODOLOGY

This chapter describes in detail the research methodology used in analyzing the B/W/K work model. Figure 3.1 presents a thought diagram detailing the logical development for this chapter. There are eight sections covered in this chapter (the research process, the type of research conducted, the design of this research, the treatment and analysis of the data, methodological issues, research limitations, expected findings, and the dissertation management plan).

Section 3.1 (the research process) is small to allow smooth reading of the presented methodology. A detailed description of the research process is provided in Appendix A for the reader who wishes to explore in more detail the researcher's views on the subject of research. In section 3.2 the specific type of research conducted is described. This is followed by a section on the specific design of this research effort (section 3.3). Here the data, subjects, and subject selection are described in detail. In section 3.4 (treatment and analysis of data), a full explanation of how the data was handled and the statistical technique used to evaluate the data is presented. This is followed by section 3.5 where critical issues dealing with methodology are discussed (representativeness, reliability, replicability, confidence, validity, and ethical issues and confidentiality). In section 3.6 the limitations of this research effort are discussed.

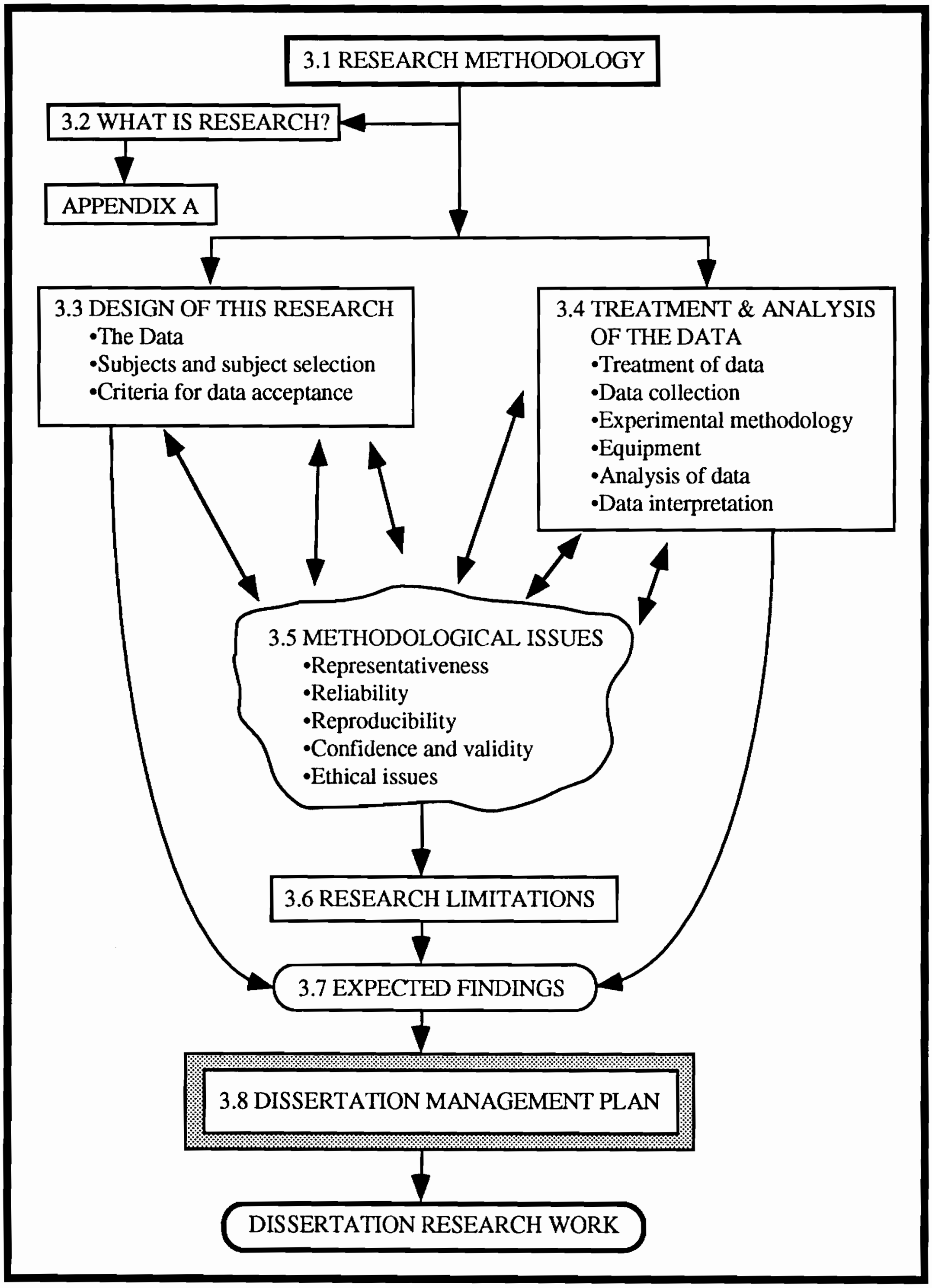

Figure 3.1 Thought Diagram Detailing Logical Development for Chapter 3.

3.1 THE RESEARCH PROCESS

Research can be approached and classified in a variety of ways (basic, applied, technological, inductive, deductive, exploratory, confirmatory, etc.). A researcher's belief of what constitutes research is critical in understanding the research effort itself. Thus, it is a good idea for the researcher to clarify for the reader his/her views, assumptions, and if possible biases (Leedy, 1989; Steinberg, 1981). The researcher's views on 'what is research?' are presented in detail in Appendix A. The following section provides the reader with the type and design of research.

3.2 TYPE OF RESEARCH CONDUCTED.

The type of research is an empirical confirmatory study on the B/W/K work model. Since this research seeks to analyze an unproved work model, the research is hard to classify with respect to its typology; basic, applied summative evaluation, formative evaluation, or action research (see Patton, 1990). The research has both traces of basic and applied research elements with respect to purpose, focus, desired results, level of generalization, and key assumptions (see Appendix A for further detail). But, the researcher believes that even though there is a good case for defining this study as applied research, the better classification is that of basic research. The ultimate determining factor in this decision is that the results contribute to the theory of work (in this case the B/W/K work model). Since the research is a confirmatory study, the logic used is deductive in nature. So this research is an basic, deductive, empirical, and confirmatory study into the nature of work, specifically on the B/W/K work model.

3.3 RESEARCH DESIGN

The driving force behind the design of this research effort is the definitions of the three work types described in the B/W/K work model (Chapter 2). The three work definitions are characterized by eight separate factors. Thus, each of these characteristics or elements is separately examined for each type of work. In analyzing questions of concepts, various methods can be used such as model cases, contrary cases, related cases, borderline cases, and/or invented cases (Wilson, 1990).[22] This research relies on 'model cases' to help clarify and distinguish the eight separate work characteristics in the three separate work types.[23] The three model cases are 'mainly' B-work represented by production operators, office/secretarial personnel positions representative of 'mainly' W-work, and university professors in science or engineering representative of 'mainly' K-work (see table 3.1). The term 'mainly' is used in the previous sentence because the B/W/K work model stipulates that all workers do each type of work, the percentage composition of each of the three types of work task requirement being the determining

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22 The use of these cases as explained by Wilson are to 'flush out' the concept (isolate the relevant ideas) and subject them to the scrutiny of scientific analysis. Note, Wilson's procedure is an eleven step process (not all the steps need to be used, nor are they necessarily to be used in sequence). The eleven steps being 1- isolate the question of concept, 2- remember there is not one single 'right answer,' 3- look at model cases, 4- look at contrary cases, 5- look at related cases, 6- look at borderline cases, 7- look at invented cases, 8- understand the social context of the problem, 9- look at possible underlying anxiety causing the problem, 10- look at the practical results of the concepts, and 11- adopt meanings (use operational definitions) to clarify ambiguous points or ideas. This approach is used in the philosophical literature, but can be extended to any area of inquiry.

23 The use of the invented case scenario was used by Beruvides and Sumanth (1987) to condition the first iteration of work definitions (refer to Chapter 2). The use of this analytical technique is powerful in fully developing concepts. It is envisioned that 'borderline' and/or 'related' cases could be used subsequent to this research effort to further detail (strong inference - see Appendix A) the study on work and the B/W/K work model specifically.

factor in specific job positions. For example, a first line supervisor does all three types of work, but it is directed that his/her work is representative of 'mainly' W-work since it is believed that the supervisors job task percentage break down will be representative of W-type work as defined by the eight characteristics in the BW/K work model (see Chapter 2).

Table 3.1. Description of Subjects for Field Study.

Field Study Subjects		
Job Type	**Data Source Subject Group**	**Hypothesized**
Production operators	local industry	Mainly B-work
Office/secretarial personnel	local industry and a research institution in the U. S.	Mainly W-work
University professor (science or engineering)	research institutions in the U. S.	Mainly K-work

The purpose of this section is to answer the what, who, when, where, why, and how the experimental design was done. Section 3.3.1 will present the specific hypotheses tested. Section 3.3.2 (the data) answers 'what' specific data was gathered for the research. Section 3.3.3 (subjects and subject selection) answers the who, when, and where with respect to the data for this research. Finally, section 3.3.4 (criteria for data acceptance) will answer 'why' the data were used. It must be noted that two pilot studies were run in April of 1992 and December of 1992 to test the feasibility of the design in the field.

Appendices B and C have a full description of the pilot studies with results and 'lessons learned.' The following sections reflect the learning acquired from the pilot study.

3.3.1 RESEARCH HYPOTHESES

A specific set of testable hypotheses (null hypotheses) were developed, from the hypotheses statements given in section 1.3.1 to test the eight characteristics of the B/W/K work model. There is a main hypothesis that is supported by eight sub-hypotheses. Each sub-hypothesis corresponds to one of the eight characteristics of the work definitions. The main hypothesis and the eight sub-hypotheses are stated in table 3.2.

3.3.2 THE DATA

The essential element in all research is the data collected. The data and the selection of the data define much of the research to be conducted. The data for this research are a result, in part, of the eight work characteristics being explored and the initial results obtained in the pilot study (Appendix B). The pilot study results demonstrated that the data collection form needed to be designed in a way that direct correspondence between the work characteristics and the work survey was present and unambiguous. Data can be of two types: primary data and secondary data (Leedy, 1989). This research gathered primary data, which are data closest to the phenomenon being investigated. The primary data to be collected are depicted in the data logging forms (see figure 3.2). Each of the three population groups (mainly B, mainly W, and mainly K work) was surveyed at random time intervals during a work day for approximately a total of 10 days (2 weeks). The subjects were required to fill out a form, when signaled by a random time interval device, on the work they were engaged in at the time (see sections

3.4.1.2, 3.4.1.3, and 3.4.1.4 for further detail of the specific methodology used).[24] The subjects had to discriminate specifically between each of the eight characteristics.[25] This is believed to be the best way to obtain primary data that are unambiguous.

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[24] The mainly W and K-work sample populations have similar methodologies, but the mainly B-work sample population used a different methodology. This is due to the work constraints of these sample populations. This is explained in detail in section 3.4.

[25] Subject training was required to assist them in discriminating the differences in the levels of each of the eight work characteristics. The training conducted is presented in section 3.4.1.5.

Table 3.2. Research Hypotheses for This Research.

Main Hypothesis- The three types of work (B, W, and K) have probability distribution functions that are independent along the 8 integral parts (outputs, inputs, type, discretion level, persuits, endeavors decision type, and maturity level) that define work, and can be described separately as follows in the sub-hypotheses postulated.

Sub-hypothesis 1- The probability distribution across tangibility levels for work *outputs* are independent with respect to B, W, or K work type.

Sub-hypothesis 2- The probability distribution across tangibility levels for work *inputs* are independent with respect to B, W, or K work type.

Sub-hypothesis 3- The probability distribution across work *type* levels are independent with respect to B, W, or K work type.

Sub-hypothesis 4- The probability distribution across work *discretion* levels are independent with respect to B, W, or K work type.

Sub-hypothesis 5- The probability distribution across work *pursuit* levels are independent with respect to B, W, or K work type.

Sub-hypothesis 6- The probability distribution across work *endeavor* levels are independent with respect to B, W, or K work type.

Sub-hypothesis 7- The probability distribution across work *decision type* levels are independent with respect to B, W, or K work type.

Sub-hypothesis 8- The probability distribution across work *maturity* levels are independent with respect to B, W, or K work type.

DATA LOGGING FORM

ID #: ______________ **DATE:**______________ **TIME:** ______________ am / pm

LOCATION: ______________________________

PRODUCT / SERVICE RENDERED: ______________________________

WHAT EQUIPMENT WAS USED? (if any): ______________________________

WHAT KNOWLEDGE IS REQUIRED FOR THIS TASK?: ______________________________

____

____

PLEASE CHECK THE APPROPRIATE BLANK FOR THE TASK AT HAND.

1. The **output(s)** produced by this task is/are- ______ Tangible ______ Intangible

2. The **input(s)** required by this task is/are- ______ Tangible ______ Intangible

3. This **type** of work task is- ______ Mainly Physical ______ Requires some Physical ______ Mainly Mental

4. The level of **discretion** I have in this work task is- ______ Little to none ______ Fair ______ High

5. The **pursuit** of this work task is a- ______ Process ______ Project ______ Program ______ Problem ______ Perplexity

6. The **endeavor** of this work task is- ______ Functional ______ Operational ______ Tactical ______ Strategic

7. The **decision(s)** I have to make for this work task is/are- ______ Structured ______ Semi-structured ______ Unstructured

8. The **maturity level** of this work task is- ______ for visibility ______ for control ______ for optimization

Figure 3.2 Research Data Logging Form.

3.3.3 SUBJECTS AND SUBJECT SELECTION

This section will explore the 'who,' 'where,' and 'when' of the research design. Specifically, there were three sample populations (mainly B, mainly W, and mainly K work subjects). The three sample populations described in the following sub-sections are believed representative (model cases) of the work types to be analyzed.

3.3.3.1 Mainly B-Work Subjects

The mainly B-work subjects were production employees in two organizations located in southwest Virginia, a state government print shop and ABC corporation.[26] Thirty one subjects were used in the study (eleven at the Print Shop and twenty at ABC corporation).[27] Twenty two males and eight females participated in the study. The participants ranged from 20 to 65 years of age. The work at the Print Shop consisted in printing pamphlets, booklets, brochures, business cards, etc. The ABC corporation produces parts for the automotive industry. These workers were chosen as subjects for the mainly B-work sample group because their job description and work tasks were found to be representative of what might be thought of as mainly B-work.[28] Included in the decision was the availability and management approval to use these workers as subjects as well as the proximity of the work location to the researcher's base of operations.[29]

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26 The names of the organizations have been changed to maintain their anonymity.

27 The reasoning used in the selection of the number of subjects used in each of the three population groups is explained in section 3.4.2.1 (How data will be analyzed).

28 A discussion with the management representative for the Print Shop and ABC corporation on the type of work these subjects do assisted the researcher in deciding to use the workers as subjects.

29 Since the mainly B-work group was surveyed by the researcher, using a more traditional work sampling technique, location proximity is an important factor in subject selection for this population sample. Also, training of subjects is required in this study (see section 3.4.1.5), so proximity of location was again viewed as important.

3.3.3.2 Mainly W-Work Subjects

The mainly W-work subjects were office / secretarial personnel from an organization (university engineering department) located in the eastern United States. Five subjects were used in the study. All participants were females, ranging from 20 to 50 years of age. Their work consisted of typing, text editing, secretarial, and data entry work. These workers were chosen as subjects for the mainly W-work sample group because their job description and work tasks were found to be representative of what might be thought of as mainly W-work.[30] Included in the decision to use these workers as subjects was availability and management approval. Proximity of location also played an important role due to the subject training required in this study, as well as ease of equipment distribution and data collection.

3.3.3.3 Mainly K-Work Subjects

The mainly K-work subjects were university professors in engineering (industrial, mechanical and electrical) from research institutions located in the southeast and midwest United States. Six subjects were used in the study. Four males and two females participated in the study. The participants ranged from 25 to 45 years of age. A job description is not an easy thing to obtain for this type of worker. The selection of university professors was done intuitively. The work position of a university professor, after discussions and interactions with various individuals holding such positions, was the determining factor in using this type worker as the mainly K-work group representatives. The deciding factor used on an individual basis was if the worker is a faculty member

[30] The decision to use these subjects was also based on conversations with the University department management representatives as to the representativeness of the workers' work.

with both teaching and research responsibilities. Research associates in university laboratories and faculty administrators were excluded. There are two reasons for this. First, lacking one of the two major characteristics sought in these workers (teaching or research work) made the individual non-representative of the 'average worker' in this job type. Secondly, as will be seen in section 3.4.2, the statistical model used required homogeneity in the sample population (stratified sampling technique). Worker location, although important, was not as crucial since self-logging was the means of data collection.

3.3.4 CRITERIA FOR DATA ACCEPTANCE

One of the basic elements of research is the interpretation of data. Not all data are good data (mistakes, etc.) and the quality of the data is a determining factor in the quality of the results obtained. Therefore, common sense and discretion was employed by the researcher when dealing with the data collected.[31] To administer control over the amount and quality of data collected (primary data), data collection was restricted to the information obtained from the data logging form as described in section 3.3.2 (see figure 3.2) and exit interview held with subjects. The form was designed to collect specific data related to the hypothetical statements anchoring this research design. All secondary data, such as researchers observations, conversations, or questions by subjects were duly recorded. This secondary data, although important, were classified and treated separately.

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[31]The researcher's discretion was used when clear evidence of data integrity was in question. All instances of this nature were duly recorded in the researcher's field data log.

3.4 TREATMENT AND ANALYSIS OF DATA

In this section the 'how' of the research is described; specifically how the data were treated (collected, field work methodologies to be used, equipment, and subject training). This is followed by how the collected data were analyzed and interpreted (statistical design incorporated to test for data significance).

3.4.1 TREATMENT OF DATA

As indicated in section 3.3, the primary data collected were the eight work characteristics recorded on the data logging form for the three sample populations used in this research. Described below is how the data were specifically treated (collected, field work methodology used, equipment, etc.).

3.4.1.1 How Data were Collected

Data collection was restricted to the information entered on to the data logging forms, formal interviews (primary data), and any observations, questions, problems, etc. the researcher encountered in the field work phase of the project (secondary data). Because the three sample population groups have markedly different work requirements, more than one data collection methodology was used to accommodate this population diversity. Two specific methodologies were used: a- a self logging technique (section 3.4.1.2) and b- work sampling (section 3.4.1.4).

3.4.1.2 Subject Self-Logging Methodology

The self logging methodology was used by both the mainly W and the mainly K-work groups. The self logging methodology consisted of each individual subject (11 in all, 5 W-work subjects and 6 K-work subjects) having both a random time generating device (see section 3.4.1.3) and a work log (notebook filled with data logging forms).

Throughout the work day for a period of ten days (2 weeks)[32], the subjects filled out a separate data form at the cue from the beeper device.

3.4.1.3 Equipment

The random time generating devices used for the field work were model DWO2 Datawriter instruments produced by the Royal J. Dossett Corporation of Excelsior, Minnesota (see Appendix D). The devices are 1 x 2 x 5.5 inches in size, with a weight of 6 ounces, powered by a rechargeable NiCd battery pack. These devices are standard off-the-shelf work sampling recorders regularly used by industrial engineers in industry. The devices have many functions, but were used only as random timing generation beepers. The random time sequence was programmed into the Datawriters by the researcher prior to distributing to the subjects. Under a full charge and only using the random beeper program, the devices can run for over 30 days on one charge.

The random time was programmed to beep on average every 30 minutes. The minimum time lapse between beeps was 3 minutes and the maximum 57 minutes (the range one can set on the Datawriters is 10% to 190% of the average time desired). There are several (over 30) random tables in the Datawriters memory banks with 19 numbers ranging from .1 to 1.9 at .1 increasing intervals (representing the 10% to 190% range described above).

3.4.1.4 Work Sampling Methodology

The mainly B-work group was sampled using the same data logging form, but in this case the Datawriters were not used. Production personnel could not be asked to be

[32] The reasoning used in the selection of the field work time span is explained in section 3.4.2.1.

interrupted on average 16 times a day for two weeks. Thus, the researcher served as analyst and recorded the data for the workers. The subjects were asked to respond to each of the entries on the data form. The researcher used random time tables (schedule) that extended over a 4 week period using 31 workers (see Appendix F for the specific time tables used by the analyst). This was equivalent to approximately 800 data points as recorded for both the mainly W and mainly K workers.

3.4.1.5 Subject Training

Inherent in obtaining quality primary data for this research effort was that each of the subjects understand and distinguish between each of the choices in the data logging form with respect to the eight work characteristics. To this end, each subject was trained on the procedure and definitions of the data form. The training consisted of a description and explanation by the researcher of the different terms of the data logging form followed by a small mock up data logging sequence. The materials used to train the research participants are contained in Appendix G.

3.4 METHODOLOGICAL ISSUES

There are several methodological issues that all research efforts must deal with: representativeness, reliability, replicability, and reactivity (Katz, 1983). To this, the question of validity can be added. There are four relevant 'quality' tests of research: construct validity, internal validity, external validity, and reliability (Yin, 1989), table 3.3 is a representation of these four tests of research quality. At the heart of analyzing methodological issues is the understanding by the researcher of 'what is a methodology?'

Once this is resolved, the questions (issues) of quality of research methodology can more clearly be addressed. Leedy (1989) defines methodology as "an operational framework within which the facts are placed so that their meaning may be seen more clearly," (p. 88). The operational framework or approach is then the researcher's construction of the research process itself. This is evident in the second part of the definition where it is stated 'within which facts are placed.' Finally, the definition mentions the clarification of meaning within this constructed framework. With this in mind, it is understandable that dealing with methodological issues raises the questions: How universally representative are the results?, How trustworthy are the instruments with which the results have been obtained?, Can these results be replicated?, What may have influenced the results?, How valid are the results? This section will address these questions.

Table 3.3 Quality of Research Issues. (Adapted fron Yin, 1989).

TEST	DEFINITION
Construct Validity	Establish correct operational measurement for the concept being studied.
Internal Validity	Establish a causal relationship, whereby certain conditions are shown to lead to other conditions, as distinguished from spurious relationships.
External Validity	Establish the domain to which a study's findings can be generalized.
Reliability	Demonstrate that operations of a study - such as the data collection procedures - can be repeated, with the same results.

3.4.1 REPRESENTATIVENESS

All research needs to specify just how universal or representative the results are envisioned to be. With respect to representativeness, case, field study, or experimental research is generalizable to theoretical proposition and not to the establishment of statistical generalizations of a population or universe (Yin, 1984). This is in fact what this study attempted since it is a theoretical generalization (the soundness of the B/W/K work model and definitions) that is the basis of this inquiry. The representativeness of this research is also bound by the design which is based on a 'model case' proposition of Wilson's (1990) conceptual analysis technique (section 3.3). This restricts the generalizability, but nonetheless does help define the concepts and in part answer some of the questions posted. This study, being one step in a stated research agenda, is viewed as helping resolve a portion of the agenda. Subsequent studies on the research agenda will build on this initial research and thus build or detract from the generalizability of this research. So, although this research can be viewed as representative to the extent that it is generalizable to a theoretical proposition, the researcher is fully cognizant that this research is limited in its representativeness. Even though the data being collected are generic (not tailored to any specific industry, but to work in general), the study is only representative for the present industries. The representativeness of the model can be enhanced in subsequent studies.

3.4.2 RELIABILITY

The possibility of reliability problems is always a threat to research. The question of reliability is relevant to several components of the research process: test instruments, questionnaire, etc. (Leedy, 1989). With respect to this research, the question of reliability presents two areas of concern: field work equipment and data logging instrument. First, with respect to the field work equipment (Datawriters), the random timing devices were tested to evaluate, a) the randomness of the audio cues, b) the average time interval of cues, and c) the possibility of the random time program possibly (inadvertently) being altered. The test for randomness of audio cues and average interval time of the devices were both found to be acceptable.[33] The possibility of inadvertently changing the random time sequence program is virtually non-existent. This would entail punching a number of specific keys sequentially. For this to happen, in the event that the subject bumps up against a counter or table, is so remote that it is not worth considering. Also, depressing random keys on the device does not affect the random time program.

The data logging instrument (form) was designed in its current format as a result of the lessons learned from the pilot study results (see Appendix B). The data logging instrument is a better design for the purposes of this research than the previous instrument design because it incorporates some of the lessons learned from the pilot study results. But this does not substantiate the instrument's reliability. To help assure that the data desired were in fact the data recorded, training classes were held with all subjects to familiarize them with the instrument and the meanings of each of the possible log entries. The training was standardized (written) and administered following a prescribed format so differences in information transfer from instructor to subject was diminished.

3.4.3 REPLICABILITY

Replicability, often called repeatability, is an important concern in any research effort. In fact, Leedy (1989) believes research should be repeatable to the extent that any

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[33] Conversations with Royal Dossett, the designer and manufacturer of the Datawriters, revealed that no units have been recalled or complaints registered with respect to audio cue reliability. The only field complaints that Mr. Dossett has received about the audio cue option of the Datawriters is that in heavy industrial settings, the cue is at times hard to detect. This is not viewed as a problem in this study since the subjects were not in these environments. The B-work sample group were not cued by the Datawriters but by the researcher, who was guided by random time tables.

other competent researcher under similar circumstances, using identical parameters, addressing the same problem, should achieve comparable results to the original study. This is not always the case, nonetheless, replicability is a goal that most all research designs should strive to achieve. This research effort strived for this goal by having a prescribed written and approved methodology that was strictly followed in the field. Any deviations from the norm were duly recorded by the researcher and reported in the final document.

3.4.4 CONFIDENCE

When dealing with research efforts where people are the crucial elements in the research, the concern of reactivity is a valid one. Since this research had two different methodologies (self logging and work sampling), various concerns were addressed. With respect to self-logging, little interaction occurred between the subjects and the researcher, so training of subjects needed to be uniform and objective. Any possible questions raised by the subjects using the self-logging technique during the field study itself were duly recorded by the researcher. The work sampling subjects interacted with the researcher. To assure that reactivity was not a problem, the researcher followed the written methodology as strictly as possible. Any deviation from the norm was recorded. Training subjects helped diminish the concerns with reactivity in this research effort.

3.4.5 VALIDITY

"With any type of measurement, two considerations are very important. One of these is validity; the other is reliability. Validity concerns the soundness of the measuring instrument" (Leedy, 1989; p. 26). Yin (1989) agrees with this premise and presents three types of validity: construct, internal, and external.[34] Leedy (1989) lists six types of validity: face, criterion, content, construct, internal, and external. In this section these issues are addressed. The question of face validity is very similar to representativeness. Face validity relies on the subjective judgment of the researcher (and the reader) when answering two questions: does the instrument (questionaire, etc.) appear to measure what it is supposed to measure? And, is the sample being measured adequate and representative? These two questions have been addressed in sections 3.4.1.1 and 3.5.1 respectively. Content validity of the research instrument (how well is the content addressed) was covered in the design of the instrument itself and the pilot study (section 3.3.1, 3.4.1.1, and Appendix B). The issue of construct validity is concerned with convergence and discriminability (Leedy, 1989). That is, convergence looks at different measuring methods that converge or focus the results Discriminability looks at the ability of the instrument to discriminate or differentiate the construct being studied. With respect to convergence, this research established and maintained a chain of evidence (literature review, pilot study, field work results, and observations) so that any reviewer of this research is convinced that the steps taken and the reasoning used lead to the results.

Internal validity is "the freedom from bias in forming conclusions in view of the data" (Leedy, 1989; p. 27). This is directly related to the design of the research. Are the results (dependent variables) influenced by the independent variables and not by the manner in which the research was designed? External validity "is concerned with the generalizability of conclusions reached through observation of a sample to the universe" (Leedy, 1989; p. 27). Since this study was based on hypothesis testing, the

[34] The issue of validity is addressed in several ways. For further information on the issue of research validity, Brinberg and McGraph (1985) and Champanis (1988) are suggested readings.

generalizations are statistical generalizations drawn directly from the data. In essence, what was examined here is statistical significance. Generalizations to other cases were limited since this study is the first (model case) analysis of the proposed research agenda.

3.5 RESEARCH LIMITATIONS

All research efforts have limitations. It is a difficult thing for a researcher (due to his/her proximity to the work) to list all the limitations of the proposed research to do a faithful job of presenting the limitations. Expanding on the information provided in section 1.4, this research is restricted by:

1- The research is based on a specific work model (Beruvides and Koelling (1992a and 1992b). This, although focusing the research, also confines the research to a specific paradigm.

2- The subjects used were selected from various job types. The selection of subjects used in this research was based on the researchers perception of job classifications that serve as best cases (exemplars) of each type of work. This was a judgment call on the part of the researcher since these definitions have never been tested or validated (only face validity has been used).[35]

3- Due to time and cost limitations the study was only a between group analysis (B-work, W-work, and K-work). Within group analysis (such as looking at several possible graded classifications of let's say W-work only) will be left to future studies.

4- This research makes the assumption of independence of data entries required by the statistical technique used to analyze the data. This would require a much larger sample population than is logistically possible (see section 3.4.2).

5- The data collection was strongly tied to the training of subjects and their understanding of the terms used in the data collection instrument.

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[35]The subjects are representative of 'best cases' using an informal criterion of what is generally accepted (societal norm) of blue-collar, white-collar or knowledge work. In no way were the eight characteristics used in selecting subjects.

6- This study was an initial research effort of a projected research agenda, so the results will be limited in their generalizability.

7- The design of this research is based on a 'model case' sample population which limits what can be learned about the whole population or 'Universe of Work' in this case.

CHAPTER 4

FIELD STUDY RESULTS, ANALYSIS, AND DISCUSSION

This chapter presents the result obtained from the field study conducted in February and March of 1993 (figure 4.1 is a thought diagram detailing the logical development for this chapter). In this chapter both the primary and secondary data results are addressed. The primary data consist of three sources of data: 1- the eight work characteristics data (collected from the data form - figure 3.2); 2- location, product/service, equipment usage, and knowledge data (also collected from the data form - figure 3.2); and 3- exit interviews from W and K group participants to evaluate the self-logging methodology used with these two groups.[36] The secondary data deal with the observations and thoughts of the researcher while conducting this research.

Section 4.1 introduces the chapter and sets the stage for the sections to follow. In section 4.2, the results of the eight work characteristics data are presented in detail. Section 4.3 follows with statistical data analysis of each of the eight work characteristics where the contingency tables and statistical results are presented and analyzed. In section 4.4, the results of the location, product/service, equipment usage, and knowledge data for each of the three population groups are presented and analyzed. This is followed by section 4.5 where general discussion of the results (work characteristics and other data) are evaluated.

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[36] A full description of the results of the exit interviews can be found in Appendix H. The discussion of the exit interview results in this chapter are limited to what has been learned from the interviews.

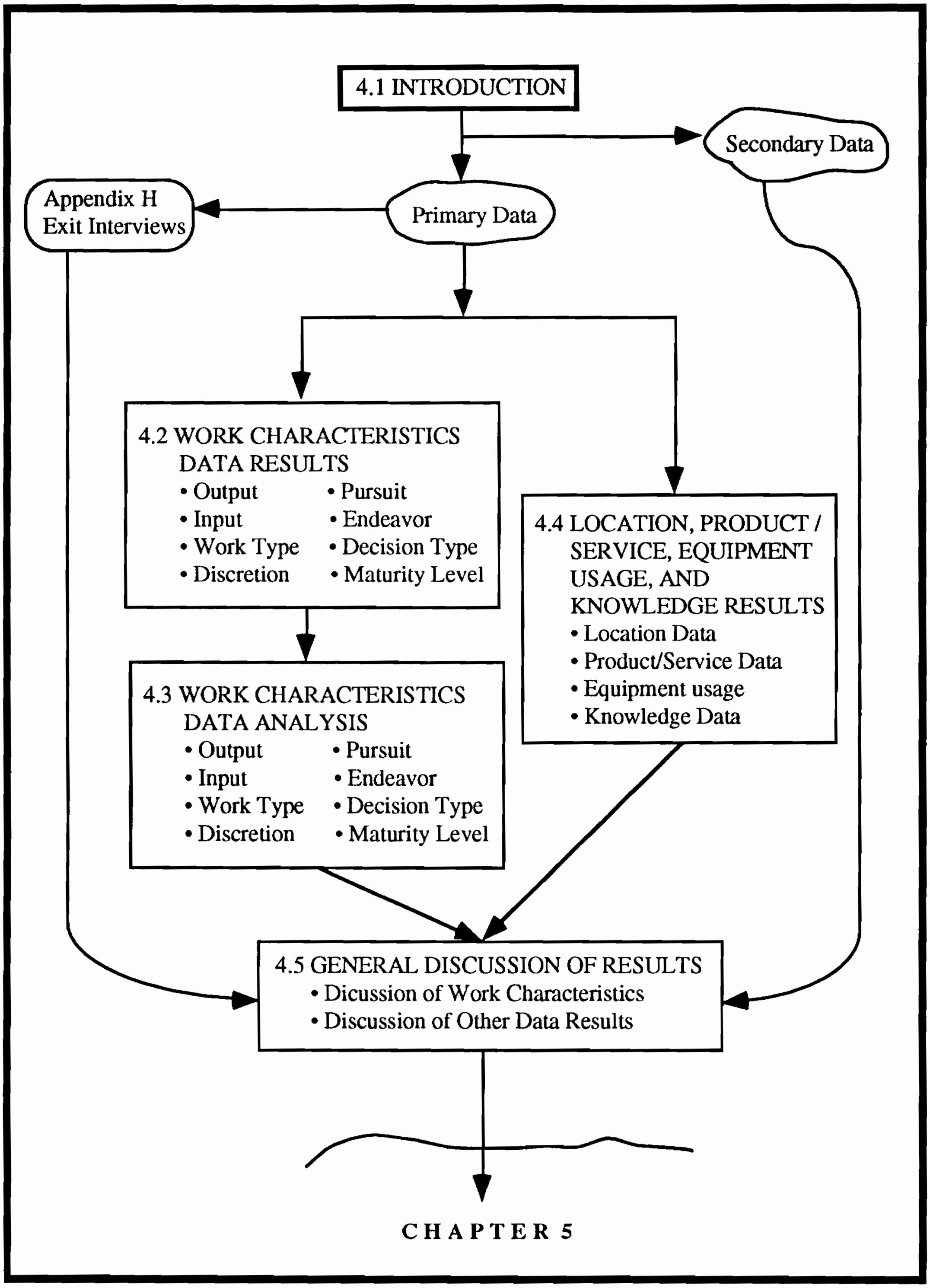

Figure 4.1 Thought Diagram Detailing Logical Development for Chapter 4.

4.1 INTRODUCTION

The following sections deal with the data gathered in the field study conducted. Data collection can be obtained in several manners. There are primary data (that have been directly measured) and secondary data (the data not directly measured, but providing useful input to any research). In sections 4.1.1 and 4.1.2 an overview of the data (primary and secondary respectively) is presented, followed by a detailed analysis of the primary data in sections 4.2, 4.3, and 4.4.

4.1.1 PRIMARY DATA COLLECTED

This study provided three sources of primary data: the eight work characteristics data, the location, product/service, equipment usage, and knowledge data, and, finally, exit interview data. Since sections 4.2 through 4.4 deal in detail with the eight characteristics data and the location, product/service, equipment usage, and knowledge data, they will not be addressed here. Exit interviews were conducted with all eleven W and K group participants. These were one-on-one interviews consisting of eight questions addressed to the participants by the researcher. Appendix H contains the questions and responses of the interviews. The questions, in general, addressed the following:

- describe, give your opinion of the data collection methodology,
- what are the weaknesses of the methodology?,
- the strengths?,
- what would you change in the methodology?,
- what would you keep the same?,
- was the methodology effective?,
- give suggestions on how to improve the methodology, and

• any other comments.

The main reason for the exit interviews was to gather, in an informal manner, input on how to improve the self-logging data collection methodology.

The results yielded a duality of responses (see Appendix H for further detail). The majority (8 out of 11) found the methodology to be effective in gathering the data desired. The remaining three respondents found the methodology effective 'to some extent.' No respondent found the methodology ineffective, even the biggest critics among the participants. Also, the beeper and randomness of the methodology was found to be a strong point, with the terminology (definitions) being considered by many as weak (hard to understand). The researcher was aware of this point prior to conducting the study.[37] It was decided that for this research, being the initial study in a research agenda, altering definitions obtained from the body of knowledge (literature) would not be sound. This is definitely an issue that needs to be addressed in subsequent studies. Overall, the self logging methodology, although intrusive, did serve the intended purpose.

4.1.2 SECONDARY DATA COLLECTED (OBSERVATIONS)

Four major points were observed that could be useful to those conducting similar work study research. First, the B group data collection, per individual, took less time than expected due to the repetitious nature of work. Many observations were identical to the previous ones taken, thus the operators were interrupted for less time than had been originally planned. Secondly, contingencies are a crucial aspect of all project management. This research was confronted with a major problem, the random time devices (beepers) did not work as planned. The beeper devices worked properly with

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[37] The committee raised this same question during the proposal defense meeting.

respect to the basic functions (cueing participants), but the devices were supposed to last a full four weeks on a single charge if only the beeping option was used. In fact, only one of the fifteen devices employed (eleven in the field and four back ups) worked as specified. The researcher had tested the devices prior to putting them in the field. The problem was noticed and the devices mailed to the vendor to fix the problem and upgrade some of the devices' beeping functions. The testing and repair were done in October through December of 1992 so the devices would be ready for the January 1993 start up. Even after repair, the devices did not work as specified. So, a second contingency was implemented. The participants were provided with a battery charger and asked to charge the devices at the end of each work day. This solved the problem, but created another inconvenience for the study participants.[38]

Thirdly, the amount of data collected in this study (close to 18,000 data points) was a large number. These data were hand tabulated, a very time consuming and error prone method. It may be a good idea to use some type of computer form in the future (at least for the eight work characteristics data). Finally, the training can be improved. Various participants using the self logging methodology encountered problems.[39] It may be a good idea to do more extensive training and test participants before allowing them to be subjects.

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[38] Some participants forgot to charge their devices on several occasions and missed a day of data collection. This caused the subjects to have to extend their data collection time frame.

[39] This is evident in the data forms, where many readings were altered by the subjects after they initially recorded the data.

4.2 WORK CHARACTERISTICS RESULTS

Sections 4.2.1 through 4.2.8 present the data collected in the field study pertaining to the eight work characteristics of the B/W/K work model. Each section presents the data in tabulated form with a bar graph depicting the data along with a brief explanation of the results. In section 4.3 these data are then analyzed statistically.

4.2.1 OUTPUT DATA RESULTS

The output characteristics data (Tabel 4.1 and Figure 4.2) resulted in a trend that is very much what was expected (hypothesized). As can be seen, the B group has the largest amount of tangible outputs and the smallest amount of intangible outputs (proportionally). This trend is reversed with the K group, with the W group somewhere in between. This is supportive of the B/W/K work model conception.

Table 4.1. Count of Tangible and Intangible Outputs by Work Type.

1- OUTPUTS	TANGIBLE	INTANGIBLE
B Group	726	136
W Group	498	125
K Group	313	408

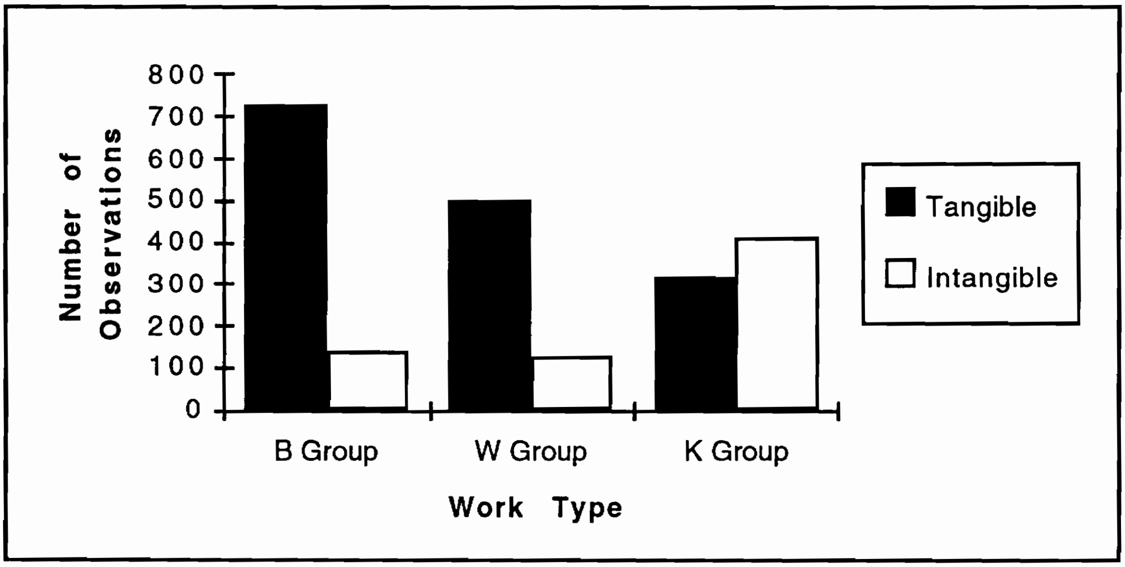

Figure 4.2. Tangible and Intangible Outputs by Work Type

4.2.2 INPUT DATA RESULTS

The input characteristics data (Table 4.2 and Figure 4.3)also revealed a trend that reflects what the researcher expected (hypothesized). The input characteristics data show an even stronger trend than the output data, and thus are supportive of the B/W/K conceptual model.

Table 4.2. Count of Tangible and Intangible Inputs by Work Type.

2- INPUTS	TANGIBLE	INTANGIBLE
B Group	812	50
W Group	531	92
K Group	229	492

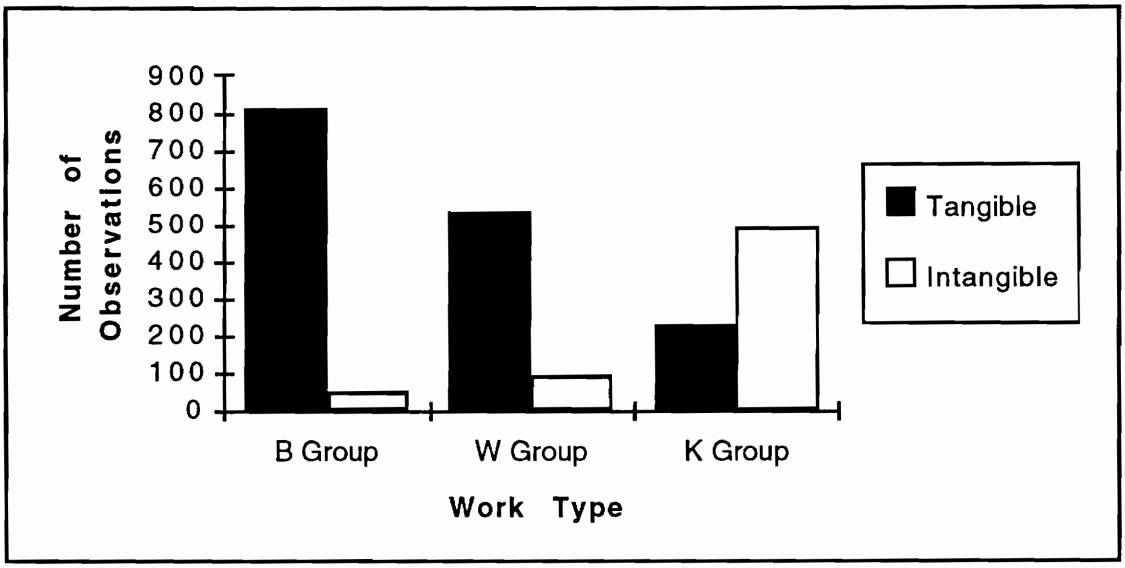

Figure 4.3. Tangible and Intangible Inputs by Work Type.

4.2.3 WORK TYPE DATA RESULTS

The work type characteristic data (Table 4.3 and Figure 4.4) show strong results. Figure 4.4 shows the expected data trends well. The B group is skewed toward the physical work classification, the K group data toward the mental with the W group a more leveled or flat distribution across the three classifications. This again is reflective of the B/W/K work model contention.

Table 4.3. Count of Work Type Results by Group.

3- WORK TYPE	MAINLY PHYSICAL	SOME PHYSICAL	MAINLY MENTAL
B Group	753	81	28
W Group	217	287	119
K Group	82	179	460

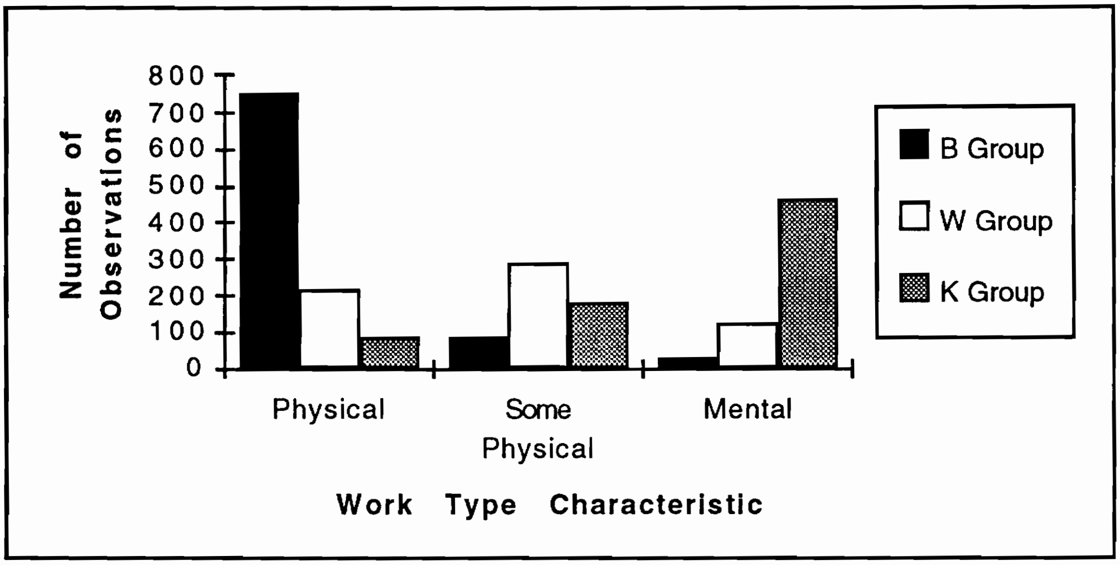

Figure 4.4. Work Type Results by Group.

4.2.4 DISCRETION LEVEL DATA RESULTS

The discretion level work characteristic showed trends similar to that of the work type with a data skew toward the low end for the B group data and toward the high end for the K group. The W group, again, situated somewhere in between with a slightly lower tail skew toward the low end. The results are posted in Table 4.4, with Figure 4.5 providing the bar graph representation. The data here again show a visual trend that is indicative of the B/W/K work model hypotheses.

Table 4.4. Count of Discretion Level Results by Group.

4- DISCRETION	LITTLE	FAIR	HIGH
B Group	771	70	21
W Group	294	249	80
K Group	62	317	342

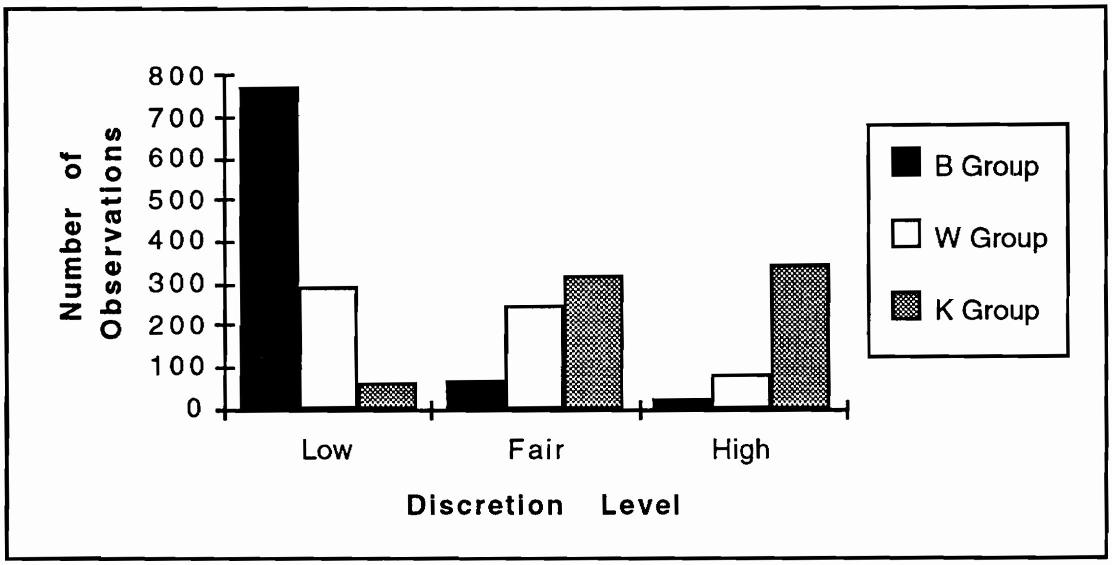

Figure 4.5. Discretion Level Results by Group.

4.2.5 PURSUIT LEVEL DATA RESULTS

The pursuit level work characteristc data (Table 4.5 and Figure 4.6) show a strong tendency for the B group data toward the process and project classifications. The W group data shows a bit more central tendency, but it is still skewed toward the lower end. The K group data skew toward the high end,. The statistical analysis (developed later) supports the B/W/K work model.

Table 4.5. Count of Pursuit Level Results by Group.

5- PURSUITS	PROCESS	PROJECT	PROGRAM	PROBLEM	PERPLEXITY
B Group	692	137	14	14	5
W Group	307	157	133	15	11
K Group	74	275	208	123	41

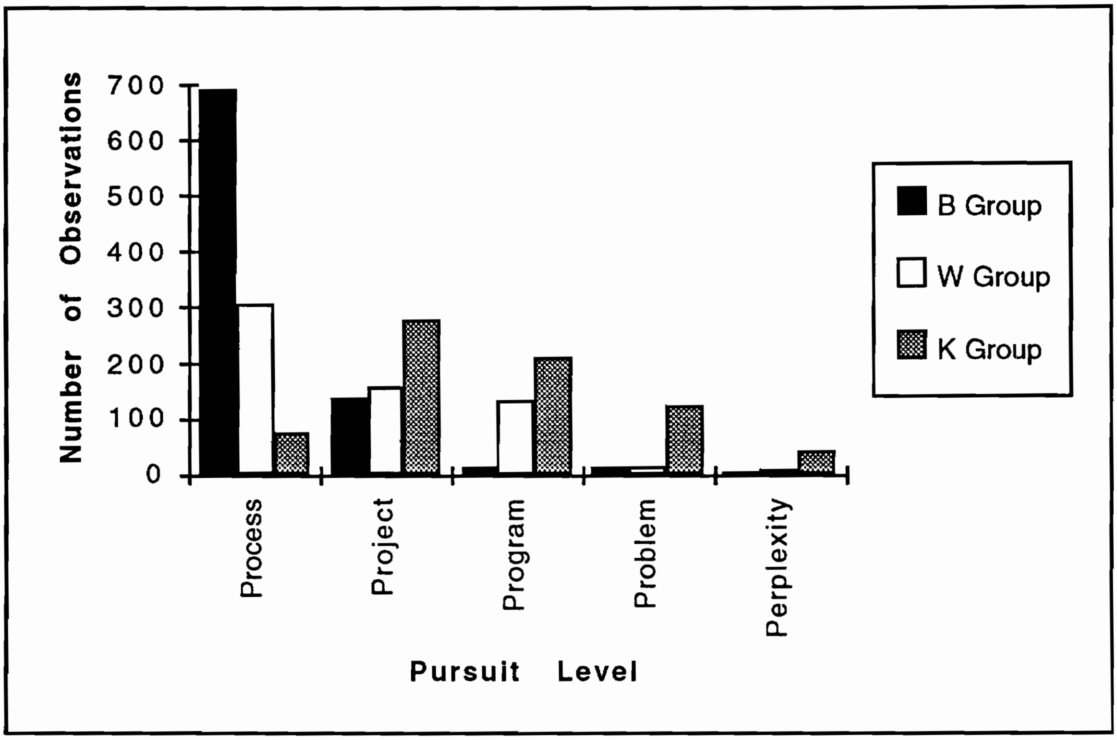

Figure 4.6. Pursuit Level Results by Group.

4.2.6 LEVEL OF ENDEAVOR DATA RESULTS

The endeavor level characteristic data are presented in Table 4.6 and visually represented in Figure 4.7. Like the the pursuit level data, a strong lower end skew is noticeable for the B group data. The W and K group data results, although not as strongly located as expected, show a distinct difference to the other group results, which yielded a statistical significance upon evaluation.

Table 4.6. Count of Endeavor Level Results by Group.

6- ENDEAVORS	FUNCTIONAL	OPERATIONAL	TACTICAL	STRATEGIC
B Group	784	53	19	6
W Group	474	120	23	6
K Group	145	202	242	132

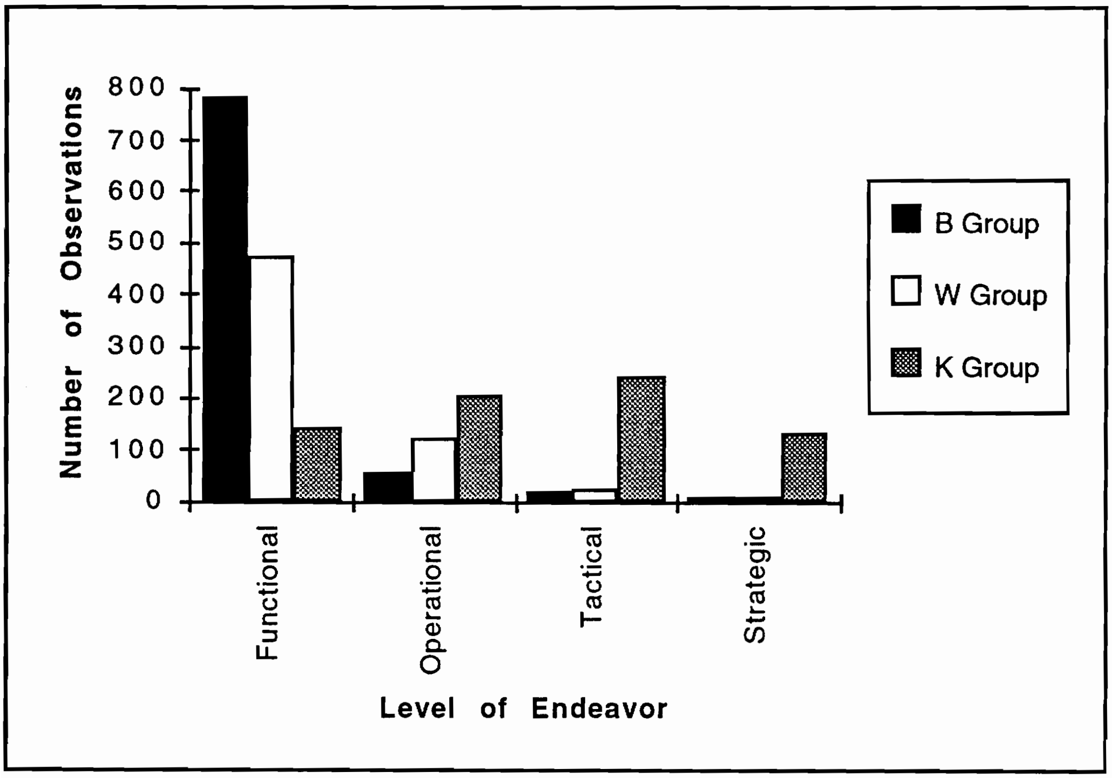

Figure 4.7. Endeavor Level Results by Group.

4.2.7 DECISION TYPE DATA RESULTS

The decision type data show marked differences in a between group comparison (visual). See Table 4.7 and Figure 4.8 for the results of this work characteristic. The B group data show a marked lower end skew. The W group data show a less pronounced lower tail skew, and the K group data show an almost bell shaped configuration.

Table 4.7. Count of Decision Type Results by Group.

7- DECISION TYPE	STRUCTURED	SEMI-STRUCTURED	UNSTRUCTURED
B Group	760	74	28
W Group	381	219	23
K Group	102	518	101

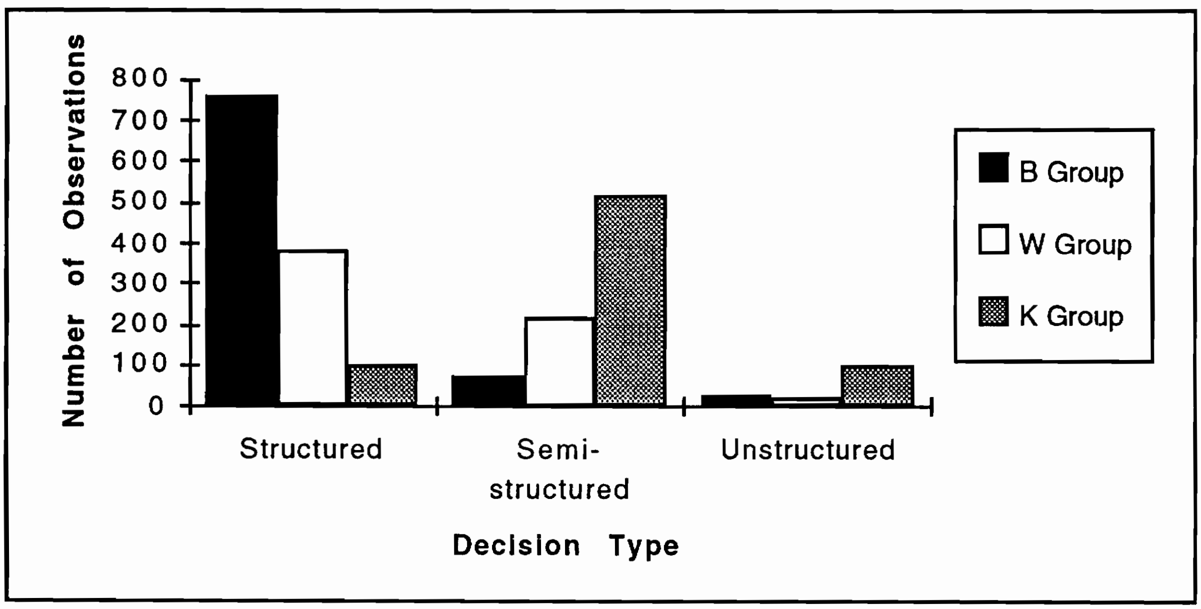

Figure 4.8. Decision Type Results by Group.

4.2.8 MATURITY LEVEL DATA RESULTS

The maturity level work characteristic data (Table 4.8 and Figure 4.9) show (visually) the least amount of differences (excluding the B group data, which are skewed toward the lower end). The W and K group data are flatter. Although, if one looks at the optimization classification by itself, the expected trend is visible. The visibility classification also shows, to some extent, the expected trend. The control classification is not as distinctly demarcated.

Table 4.8. Count of Maturity Level Results by Group.

8- MATURITY LEVEL	VISIBILITY	CONTROL	OPTIMIZATION
B Group	758	77	27
W Group	368	186	69
K Group	290	204	227

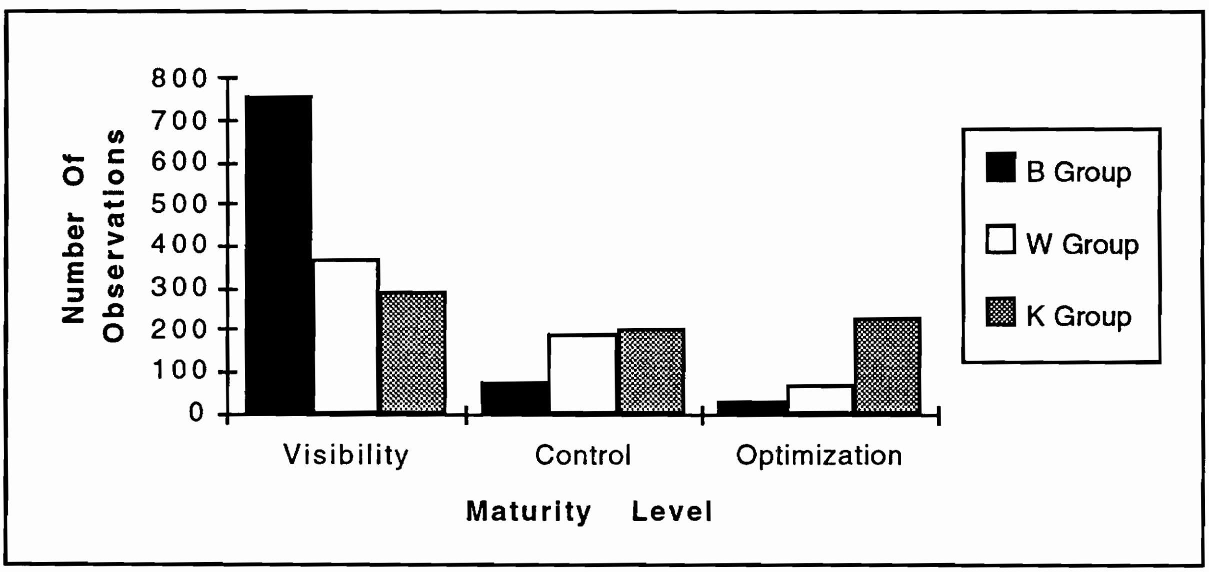

Figure 4.9. Maturity Level Results by Group.

4.3 WORK CHARACTERISTICS DATA ANALYSIS

The previous section presented the results obtained in the field study for all eight work characteristics (outputs, inputs, work type, discretion level, pursuits, endeavors, decision type, and maturity level). In this section, the statistical data analysis methodology is described and findings are presented. The evaluation will cover two separate efforts: statistical analysis and results interpretation.

4.3.1 METHOD OF ANALYSIS

The statistical technique used to evaluate the data was contingency table analysis, which is a modified chi-squared analysis. The data were tabulated into the contingency table format (tables 4.9 through 4.16) and run through the Virginia Tech mainframe computer (IBM 3090) using the SAS statistical package (Version 6.03) to calculate the results. The following sections describe how the data were analyzed, interpreted, and evaluated with respect to their validation (or rejection) of the research hypotheses postulated by this research, in the context of the B/W/K work model.

4.3.1.1 How Data were Analyzed

The amount of data in this research is large when one considers there are 3 sample populations, at least 5 subjects per sample population,[40] eight work characteristics (tables), and an average of 16 data entries per day over 10 days of field research (20 for the mainly-B group). The final count rendered 17,648 data recorded in the field study.[41]

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[40] For the B-work group, more subjects were used with less observations per subject so the average numbers projected here are equivalent to those of W and K work groups.

[41] The reasoning used to select the number of subjects and field-work time frame was based on calculations derived from the work sampling equation for sample size [$SP = 1.645\ (P(1-P)/N)^{1/2}$] (see Niebel, 1988). Where S is the desired accuracy; P is the ratio

The data were organized along each of the eight separate work characteristics (outputs, inputs, discretion level, etc.) and were aggregated within the three sample populations (B, W, and K work).[42] This resulted in an average of 735 data per work characteristic per sample group tabulated in eight separate tables (one table for each of the work characteristics of the B/W/K work model). Tables 4.9 through 4.16, in sections 4.3.2 through 4.3.9, give the contingency table codification of the data in this research.

The statistical scheme used in analyzing the data was contingency table analysis (see Conover, 1971; pp. 140-166), a chi-square, nonparametric, analytical technique. The assumptions for this type of analysis are:

1. Each sample is a random sample.
2. The outcomes of the various samples are all mutually independent (particularly among samples, because independence within samples is part of the first assumption).[43]

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of observations under study to the total observations in the sample; and N is the total sample population size. An accuracy level of +/- 10% and a 90% confidence level was selected. Estimating a minimum P (proportion) of 30% for any of the categories of the 8 characteristics (P = 160 observations / 800 total observations), an accuracy (S) of 8.9% is obtained. That is, $S = [1.645\ (0.3(1 - 0.3))^{1/2} / 0.3]$; which results in S = .089. This level of accuracy is within the desired +/- 10% specified above.

[42] This is done because what was being hypothesized and tested were the definitional work characteristics in relation to the type of work (B, W, and K). This collapsing is viewed as acceptable because the sample populations are assumed to be homogeneous. In effect, the design used stratified sampling. This will be explained later in the text.

[43] The assumption of independence may have been violated in this design. In contingency table analysis, to have complete independence would require that approximately 735 separate individuals be randomly surveyed in each sample population. This is logistically a nightmare. The assumption here is that the 42 subjects sampled in the field study over multiple days are equivalent to observing 735 separate individuals in each sample population (or approximately 2,206 individual data per population group). The reason this assumption can be made is due to the homogeneity of the work of each of the members within the three sample populations.

3. Each observation may be categorized into exactly one of the c categories [*levels of the separate eight work characteristics*] or classes [*the three sample populations*] (Conover, 1977; p. 150.)[44]

This design also used a stratified sampling technique. According to Cochran (1977), stratified sampling is a preferred scheme over simple random sampling when appropriate because: 1- there is a reduction in sampling cost, 2- it can improve the logistical work encountered in large samples, 3- the stratified sample may fit the problem better,[45] and 4- a higher degree of precision can be obtained. Points 1 and 2 above of Cochran's exposition are both logical and have been touched on previously in this discussion. With respect to point 4, Cochran states "[s]tratification may produce a gain in precision in the estimates of characteristics of the whole population. It may [be] possible to divide a heterogeneous population into sub-populations, each of which is internally homogeneous. This is suggested by the name strata, with its implication of a division into layers. If each stratum is homogeneous, in that the measurements vary little from one unit to another, a precise estimate of any stratum can be obtained from a small sample in that stratum. These estimates can then be combined into a precise estimate for the whole population" (Cochran, 1977; p. 89).

What is argued here is that there exists a whole population, in our case all workers. This population was stratified so as to increase the precision of information gathered on characteristics of the population (in our case the eight work characteristics). This stratification did not require large samples (the stratum demonstrating internal homogeneity), and in turn increased our precision on the characteristics examined with

[44] Phrase in italics added to emphasize the design used in this research effort.
[45] This is very true of this research. The stratified design intuitively fits the problem better than simple random sampling.

respect to the whole population. The statistical design used for this research is thus believed to be representative of the problem addressed.

4.3.1.2 Data Interpretation

The data, once codified, were analyzed using the SAS program in Virginia Tech's computing center mainframe. Each of the eight individual work characteristics were analyzed to see if the null hypothesis was rejected or accepted (refer to section 3.3.1; Research Hypotheses).[46] The following sections present the individual statistical analyses for each of the eight work characteristics of the B/W/K work model.

4.3.2 OUTPUT DATA ANALYSIS

The output characteristic data were placed into a contingency table analysis format (Table 4.9). The chi-squared analysis yielded a p value that was much smaller than .001 ($p \ll 0.001$), thus null sub-hypothesis 1 was rejected ('the probability distribution across tangibility levels for work outputs are independent with respect to B, W, or K work type'). From this it can be said with a high degree of confidence that the probability distribution functions across tangibility levels for work outputs with respect to B, W, or K work type are not independent and homogeneous.

In order to assess differences between specific work types, a second one tailed (2X2) chi-squared analysis was run on ordered pairs[47] (B-W and W-K) to distinguish if in fact the skew is present where the B/W/K work definitions postulate they are (B output tangibility > W output tangibility > K output tangibility).[48] Both resulted in a rejection

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[46] Some further suggested readings on chi-squared analysis are Cochran, 1952; Cochran, 1954; and Cochran, 1968.

[47] Refer to Conover (1971), pages 140-145 on (2X2) contingency table analysis.

[48] To account for type 1 error due to the two additional tests being run, the alpha level was set at .05 (the original being at .10). This was done using Bonferoni's method.

of the null hypothesis (the null hypotheses being that B output tangibility is less than or equal to W output tangiblity; and W output tangiblity is less than or equal to K output tangibility respectively). B output tangibility was found to be greater than W output tangibility ($p = 0.0343$), and W output is more tangible than K output ($p << 0.001$). Thus, it can be inferred that the B/W/K definitions with respect to output tangibility are supported by these results.

Table 4.9 Contingency Table Listing Output Characteristic Results

	OUTPUT VARIABLE		
	Tangible	**Intangible**	
B-work	726	136	$\Sigma P_{obj} = 862$
W-work	498	125	$\Sigma P_{owj} = 623$
K-work	313	408	$\Sigma P_{okj} = 721$
	$\Sigma P_{oi1} = 1,537$	$\Sigma P_{oi2} = 669$	Total = 2,206

4.3.3 INPUT DATA ANALYSIS

The input characteristic data are presented in Table 4.10. The chi-squared analysis yielded a $p << 0.001$, thus rejecting the null sub-hypothesis 2 ('the probability distribution across tangibility levels for work inputs are independent with respect to B, W, or K work type'). It can thus be said that the probability distribution function across tangibility levels for work inputs with respect to B, W, or K work type are not independent and homogeneous. The one tailed (2X2) chi-squared test on ordered pairs (B-W and W-K) both rejected the null hypothesis. The null hypotheses being, B input tangibility is less than or equal to W input tangiblity; and W input tangiblity is less than or equal to K input tangibility respectively. B input was found to be more tangible than W output ($p << 0.001$), which in turn is more tangible than K output ($p << 0.001$). Thus, the B/W/K work definitions with respect to input tangibility are supported by these results.

Table 4.10 Contingency Table Listing Input Characteristic Results

	INPUT VARIABLE		
	Tangible	**Intangible**	
B-work	812	50	ΣP_{ibj} = 862
W-work	531	92	ΣP_{iwj} = 623
K-work	229	492	ΣP_{ikj} = 721
	ΣP_{ii1} = 1,572	ΣP_{ii2} = 634	Total = 2,206

4.3.4 WORK TYPE DATA ANALYSIS

The contingency tabulated data for the work type characteristic can be found in Table 4.11. The chi-squared analysis resulted in a p value much less than 0.001 ($p << 0.001$). Subhypothesis 3 ('the probability distribution across work type levels are independent with respect to B, W, or K work type') was rejected. Thus, it can be said that probability distribution across work type levels (mainly physical, some physical, and mainly mental) is not independent and homogeneous with respect to B, W, or K type work. A one tail chi-square test was run on the (3X3) cell. This required collapsing cells [to a (2X2) configuration] to be able to run the analysis. Note, there does not exist an alternative to this for (r X c) contingency tables. Thus, when testing to see if the B group physical work type results are larger than that of the W group physical work type results (Hypothesis: $P_{bwp} <= P_{wwp}$), the values for the 'some-physical' and 'mainly mental' were collapsed (added) to form one cell; thus, making the (2X2) table. To do this for both the B-W and W-K analysis required six different one tail (2X2) contingency table analyses. The results of these tests, as well as all other work characteristics (2X2) one tail tests, are summarized in Table 4.29 in section 4.5.1. All six (2X2) analysis resulted in a rejection of the null hypothesis, ($p << 0.001$). These results support the B/W/K work model defintions.

Table 4.11 Contingency Table Listing Work Type Characteristic Results

	WORK TYPE VARIABLE			
	Mainly Physical	**Some Physical**	**Mainly Mental**	
B-work	753	81	28	ΣP_{tbj} = 862
W-work	217	287	119	ΣP_{twj} = 623
K-work	82	179	460	ΣP_{tkj} = 721
	ΣP_{ti1} = 1,052	ΣP_{ti2} = 547	ΣP_{ti3} = 607	Total = 2,206

4.3.5 DISCRETION LEVEL DATA ANALYSIS

The discretion level characteristic data are shown in Table 4.12. The chi-squared analysis resulted in a rejection of the null (sub-hypothesis 4; 'the probability distribution across work discretion levels are independent with respect to B, W, or K work type') with a p value << 0.001. The one tail (2X2) ordered pair analysis (six in all due to the 3X3 composition of the data) resulted in a rejection of the null in all cases but one (Table 4.29). Only the W-K data with respect to the 'fair' classification resulted in a failure to reject the null hypothesis ($p = 0.1557$). This indicates that the W and K group have similar (homogenous) values with respect to discretion level task that are classified as 'fair amount of work discretion.'

Table 4.12 Contingency Table Listing Discretion Characteristic Results

	DISCRETION VARIABLE			
	Little to None	**Fair**	**High**	
B-work	771	70	21	$\Sigma P_{dbj} = 862$
W-work	294	249	80	$\Sigma P_{dwj} = 623$
K-work	62	317	342	$\Sigma P_{dkj} = 721$
	$\Sigma P_{di1} = 1{,}127$	$\Sigma P_{di2} = 636$	$\Sigma P_{di3} = 443$	Total = 2,206

4.3.6 PURSUIT LEVEL DATA ANALYSIS

The pursuit level characteristic data are provided in Table 4.13. This work characteristic resulted in a rejection of the null for sub-hypothesis 5 ('the probability distribution across work pursuit levels are independent with respect to B, W, or K work type'), with $p << 0.001$. Thus, the probability distribution across work pursuit levels are not independent and homogeneous with respect to B, W, or K work. The ten separate one tail (2X2) ordered pair contingency table analysis results are provided in Table 4.29. All tests were found to be significant (except the B group 'problem' classification ($p = 0.2204$).

Table 4.13 Contingency Table Listing Work Pursuit Characteristic Results

	WORK PURSUIT VARIABLE					
	Process	**Project**	**Program**	**Problem**	**Perplexity**	
B-work	692	137	14	14	5	$\Sigma P_{pbj} = 862$
W-work	307	157	133	15	11	$\Sigma P_{pwj} = 623$
K-work	74	275	208	123	41	$\Sigma P_{pkj} = 721$
	$\Sigma P_{pi1} = 1073$	$\Sigma P_{pi2} = 569$	$\Sigma P_{pi3} = 355$	$\Sigma P_{pi4} = 152$	$\Sigma P_{pi5} = 57$	Total = 2206

4.3.7 LEVEL OF ENDEAVOR DATA ANALYSIS

The level of endeavor work characteristic data resulted in a rejection of sub-hypothesis 6 ('the probability distribution across work endeavor levels are independent with respect to B, W, or K work type'; $p << 0.001$) when analyzed using the chi-squared analysis. This indicated that the probability distribution across work endeavor levels are not independent and homogeneous with respect to B, W, or K work type. Further analysis (one tail (2X2) ordered pairs) resulted in a rejection of all null hypotheses except for the 'tactical' and 'strategic' classifications for the B-W (2X2) tables (Table 4.29). The tactical classification test resulted in $p = 0.089$ and the strategic classification in $p >> .250$.

Table 4.14 Contingency Table Listing Endeavor Level Characteristic Results

	ENDEAVOR LEVEL VARIABLE				
	Functional	**Operational**	**Tactical**	**Strategic**	
B-work	784	53	19	6	$\Sigma P_{ebj} = 862$
W-work	474	120	23	6	$\Sigma P_{ewj} = 623$
K-work	145	202	242	132	$\Sigma P_{ekj} = 721$
	$\Sigma P_{ei1} = 1,403$	$\Sigma P_{ei2} = 375$	$\Sigma P_{ei3} = 284$	$\Sigma P_{ei4} = 144$	Total = 2,206

4.3.8 DECISION TYPE DATA ANALYSIS

Table 4.15 lists the decision type characteristic data. The chi-squared results indicate that the null for sub-hypothesis 7 ('the probability distribution across work decision type levels are independent with respect to B, W, or K work type') is rejected (p << 0.001). Thus, it can be said that the probability distribution across work decision type levels are not independent and homogeneous with respect to B, W, or K work types. The one tailed (2X2) ordered pairs analysis (eight tests in all) yielded a rejection of the null hypothesis in all cases but one classification (see Table 4.29). The unstructured decision type classification between B and W work types failed to reject the null hypothesis.

Table 4.15 Contingency Table Listing Decision Type Characteristic Results

	DECISION TYPE VARIABLE			
	Structured	**Semi-Structured**	**Unstructured**	
B-work	760	74	28	$\Sigma P_{nbj} = 862$
W-work	381	219	23	$\Sigma P_{nwj} = 623$
K-work	102	518	101	$\Sigma P_{nkj} = 721$
	$\Sigma P_{ni1} = 1{,}243$	$\Sigma P_{ni2} = 811$	$\Sigma P_{ni3} = 152$	Total = 2,206

4.3.9 MATURITY LEVEL DATA ANALYSIS

The data for the maturity level work characteristic are provided in Table 4.16. The statistical analysis resulted in a rejection of sub-hypothesis 8 ('the probability distribution across work maturity levels are independent with respect to B, W, or K work type'). Thus, it can be stated that the probability distributions across work maturity levels are not independent and homogenous with respect to B, W, or K type work. The (2X2) one tail ordered pair analysis yielded a rejection of the null hypotheses in all cases but one (Table 4.29). The 'control' classification with respect to W and K work are not significantly different.

Table 4.16 Contingency Table Listing Maturity Level Characteristic Results

	MATURITY LEVEL VARIABLE			
	For Visibility	**For Control**	**For Optimization**	
B-work	758	77	27	$\sum P_{mbj} = 862$
W-work	368	186	69	$\sum P_{mwj} = 623$
K-work	290	204	227	$\sum P_{mkj} = 721$
	$\sum P_{mi1} = 1,416$	$\sum P_{mi2} = 467$	$\sum P_{mi3} = 323$	Total = 2,206

4.4 LOCATION, PRODUCT/SERVICE, EQUIPMENT USAGE, AND KNOWLEDGE RESULTS

This section presents the primary data obtained from the data logging forms with respect to worker location, product or service rendered, equipment usage, and knowledge requirements. Although this is not part of the originally proposed research (hypothesis test), the information provides two specific benefits for work research. First, these data provide useful information about the three work groups that might serve managers, engineers, and researchers in a practical understanding of work. Second, these data serve an exploratory research function by raising questions about work itself. These two points (the practical and research implications) are explored in more detail in Chapter 5. The following sections (4.4.1 through 4.4.4) detail the results obtained. In section 4.5, the results of this and the previous work characteristics data are discussed in more detail.

4.4.1 LOCATION DATA RESULTS

The location data results are listed in Tables 4.17, 4.18, and 4.19 for the B, W and K groups, respectively. Several things are readily evident by scanning these three tables. The B group personnel are the least mobile of the workers (97.6 percent of the time at their work stations) with the K group the most mobile. The mobility is evident in another statistic, the K group was found in transit 5.3% of the time, the W group 0.5% and the B group 0.3%. Surprisingly, the K group (university professors) were either in their office, in class, or in their labs a total of 77.6% of the time, which is more than expected for this work group.[49] This defies the beliefs of most undergraduate students. Also, the K group members were in a colleague's office 3.6% of the time, the W group 2.9% of the time,

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[49] Note, evenings, weekends, and holidays were not considered in this study.

and no listing for the B group. This shows interaction for the W and K group with colleagues during work periods. These location data prove useful in that they provide another snapshot into the work environment of these three groups. The results have some interesting implications that will be further explored later in this text.

Table 4.17. Results of Subject Location.
(B Group)

LOCATION	SUM COUNT	PERCENT
1- Work station*	851	97.6
2- Conference room	12	1.4
3- Offsite (meeting)	4	0.5
4- Transit	3	0.3
5- Tool crib	1	0.1
6- Main office	1	0.1

*Since such a variety of workers was used, the data forms recorded many different work locations (composition, camara, bindery, docutech, flange, and pressroom departments), but all reflect one thing, the production workers work station location.

Table 4.18. Results of Subject Location.
(W Group)

LOCATION	SUM COUNT	PERCENT
1- Office/Desk	566	90.9
2- Colleague's desk/Office	18	2.9
3- Printer Room	10	1.6
4- Computer terminal (other than desk)	10	1.6
5- Front office	6	1.0
6- Copy room	6	1.0
7- Transit	3	0.5
8- Professor's office	2	0.3
9- Conference room	1	0.1

Table 4.19. Results of Subject Location.
(K Group)

LOCATION	SUM COUNT	PERCENT
1- Office	398	55.4
2- Classroom	112	15.6
3- Lab	47	6.6
4- Transit	38	5.3
5- Conference room	36	5.0
6- Colleague's office	26	3.6
7- Home office	14	2.2
8- Department office	14	2.2
9- Library	8	1.0
10- Administration office	6	0.8
11- Off site (hotel, etc)	6	0.8
12- Copy/Mail room	5	0.7
13- Government (sponsor's) office	2	0.3
14- Faculty conference room	2	0.3
15- Secretary's office	1	0.2
16- Post office	1	0.2
17- Car	1	0.2
18- Restaurant	1	0.2

4.4.2 PRODUCT / SERVICE DATA RESULTS

The products/services data results are provided in tables 4.20, 4.21, and 4.22 for the B, W, and K groups, respectively. The first very noticeable point between these three tables is the variety of product/service output differences. The B group lists 21 different items; the W group, 23; and the K group, 49 items. The vast majority of the B group production (78.5%) is in the direct product produced by the company (bearings, printed materials -brochures, forms, etc.). The W group sees a more fractionated production, with the largest item (typing) not exceeding 20% of the workers' production. We also see an increase in the intangibility of the products or services provided. The K group is even more fractionated with the lecture/class discussion being the single largest production item of this work group, which does not even reach 18%. The intangibility of the outputs is also evident. The activities are extremely varied and thus give an indication that the work tasks must be short-term as opposed to the B group which seems to have more continuity. These results reflect the output and input work characteristic results (sections 4.2.1 and 4.2.2) with respect to tangibility. These results also have further implications that will be explored further in this document.

Table 4.20. Results of Subject Products, or Services Rendered.
(B Group)

PRODUCTS, OR SERVICES	SUM COUNT	PERCENT
1- Product (producton of)	687	78.5
2- Maching set-up / tool change etc.	36	4.1
3- Fixing or maintenance to machine	24	2.7
4- Materials handling	23	2.6
5- Waiting for work	19	2.2

Table 4.20. Results of Subject Products, or Services Rendered, (Continued).
(B Group)

PRODUCTS, OR SERVICES	SUM COUNT	PERCENT
6- Meetings (safety, etc.)	16	1.8
7- Calibrating set-up	13	1.5
8- Inspection	13	1.5
9- Paperwork	11	1.3
10- Training	7	0.8
11- Helping or consulting with colleague	5	0.6
12- Punching in job	4	0.5
13- Scheduling jobs	4	0.5
14- Review job (proofing)	3	0.3
15- Loading a program on machine	2	0.2
16- Programming a job	2	0.2
17- Problem shooting	2	0.2
18- Filing accident report	1	0.1
19- Reading job instructions	1	0.1
20- Note to customer	1	0.1
21- None	1	0.1

Table 4.21. Results of Subject Products, or Services Rendered.
(W Group)

PRODUCTS, OR SERVICES	SUM COUNT	PERCENT
1- Typing	112	18.3
2- Office work (filing, labeling,etc.)	94	15.4
3- Editing/Proofreading	89	14.6
4- Providing information	82	13.4
5- Writing letters/Memos	58	9.4
6- Working on reports	32	5.2
7- Mail	25	4.1
8- Telephone	22	3.6
9- Making a computer drawing	19	3.1
10- Training / Class	16	2.6
11- Making copies	13	2.1
12- Data entry	13	2.1
13- Scheduling	6	1.0
14- Printing	6	1.0
15- Arranging work area	5	0.8
16- Delivering materials	4	0.7
17- Reading	4	0.7
18- Sending a fax	4	0.7
19- Working on class materials	2	0.3
20- Closing up/Shut down computer	2	0.3
21- Helping a colleague	1	0.2
22- Meeting	1	0.2
23- Making coffee	1	0.2

Table 4.22. Results of Subject Products, or Services Rendered.
(K Group)

PRODUCTS, OR SERVICES	SUM COUNT	PERCENT
1- Lecture/Class discussion	112	17.5
2- Advising students	75	11.7
3- Class lecture notes, exams, materials	51	8.0
4- Writing/Editing papers (research)	43	6.7
5- Meetings	49	7.7
6- Research	43	6.7
7- Reading	29	4.5
8- Preparing for class	25	3.9
9- Information	22	3.4
10- Talking with staff or colleague	17	2.7
11- Listening to lecture	15	2.4
12- Attending PhD Preliminary Exam	11	1.7
13- Short course materials	11	1.7
14- Copying	11	1.7
15- Talking on telephone	11	1.7
16- Thinking	9	1.4
17- Getting or responding to mail	9	1.4
18- Developing film	9	1.4
19- Directions or work to GTA	8	1.3
20- Letters	7	1.1
21- Master Thesis or PhD Dissertation Defense	7	1.1
22- Course design/Development	5	0.8
23- Awards to student (service)	5	0.8
24- Consulting	5	0.8

Table 4.22. Results of Subject Products, or Services Rendered, (Continued).
(K Group)

PRODUCTS, OR SERVICES	SUM COUNT	PERCENT
25- Preparing invited talk	5	0.8
26- Faculty activity report	4	0.6
27- Cleaning desk	4	0.6
28- Preparing presentation slides	3	0.5
29- Reviewing paper	3	0.5
30- Paperwork	3	0.5
31- Correcting papers	2	0.3
32- Filing	2	0.3
33- Setting up meeting	2	0.3
34- Signing dissertation	1	0.15
35- Help session for students	1	0.15
36- Reviewing book for future course	1	0.15
37- Talking with book representative	1	0.15
38- Literature search	1	0.15
39- Change of grade card	1	0.15
40- Reading list for PhD students	1	0.15
41- Research methodology program directory	1	0.15
42- Opinion	1	0.15
43- Picking up state car	1	0.15
44- Job design	1	0.15
45- Printing	1	0.15
46- Getting supplies	1	0.15
47- Fixing computer	1	0.15
48- Seminar	1	0.15
49- Planning	1	0.15

4.4.3 EQUIPMENT USAGE DATA RESULTS

Tables 4.23, 4.24, and 4.25 list the data results for the equipment usage of the three sample groups B., W, and K, respectively. Here again various differences are noticeable between the three groups. First, the variation in the quantity of equipment usage is evident. The K group by far used the most tools with the largest variety. But note, the largest item listed is 'none' (no tool/equipment used). This trend decreases for the W group and is the smallest for the B group. Thus, the K group produces the widest variety of outputs (previous section 4.4.2) and many times use no equipment in the production of the product or service. Here we see some stark differences in the three work groups. The B group seems tied to a smaller amount of tools and uses them for longer periods of time. The K group, on the other extreme, will many times use no tools to produce product or services, but at the same time in their work day will require the use of large number and variety of tools. The W group lies somewhere in between. Thus, the three work groups are again different along another dimension, and the results present further points of interest when analyzing these work groups from a work methods standpoint. In chapter 5, a detailed look at the research and practical implications of this will be addressed.

Table 4.23. Results of Subject Work Equipment Usage.
(B Group)

EQUIPMENT USED	SUM COUNT	PERCENT
1- Production equipment*	686	74.0
2- Knife/Scissors/Tape/Straight edge	55	5.9
3- None**	50	5.4

Table 4.23. Results of Subject Work Equipment Usage.
(B Group)

EQUIPMENT USED	SUM COUNT	PERCENT
4- Tool kit†	33	3.6
5- Pen/Pencil	18	1.9
6- Inspection gages (calipers, etc.)	16	1.7
7- Material handling equipment††	15	1.6
8- Cleaning materials (rags, sponges, etc.)	13	1.4
9- Production materials#	11	1.2
10- Paperwork (department documentation)	7	0.8
11- Table	7	0.8
12- Hagan system	6	0.7
13- Densitometer	2	0.2
14- Magnifying glass	2	0.2
15- Glue	2	0.2
16- Scotch pad	1	0.1
17- Die	1	0.1
18- Telephone	1	0.1
19- Blue print	1	0.1

*. Production equipment varied quite a bit since 31 separate individuals participated in the study. Among the production equipment used were: Xerox Docutech, Vertical press, Multi 1360 press, Heidelberg press, Miehle 38 press, Miehle 25 press, saddle binder, light table, 3M plate processor, 300 ton press, Height broach, Height gage, Facer, Deburr/shear machine, Wall broach, computer, scanner, waxer, camera, photo processor, 20/20 Veritype computer, punch, plate burner, Lip unit, paper cutter

**. This number is high due to the number of times certain production employees were waiting for work. At one of the sites, a work area was being phased out. Several employees were being retrained and thus at times not working (waiting for work).

†. Tool kit comprises such tools as Allen wrenches, Crescent wrenches, screwdrivers, hammers, etc.

††. Such things as skids, dollies, overhead conveyors, bins, etc.

#. Production materials comprised such things as cutters, end plates, rollers, ink, packing blankets, etc.

Table 4.24. Results of Subject Work Equipment Usage.
(W Group)

EQUIPMENT USED	SUM COUNT	PERCENT
1- Computer	381	53.3
2- None	153	21.4
3- Office equipment*	53	7.4
4- Telephone	38	5.3
5- Typewriter	28	3.9
6- Printer/Laser printer	22	3.0
7- Copy machine	12	1.7
8- Manuals	10	1.4
9- Dictating machine	10	1.4
10- Fax machine	4	0.6
11- Dictionary	2	0.3
12- Mailbox	1	0.1
13- Coffee machine	1	0.1

*Such tools as paper cutters, letter opener, highlighter, calculator.

Table 4.25. Results of Subject Work Equipment Usage.
(K Group)

EQUIPMENT USED	SUM COUNT	PERCENT
1- None	213	22.8
2- Computer	141	15.1
3- Pen/Pencil, etc.	100	10.7
4- Laser printer	99	10.6
5- Text books	52	5.6
6- Telephone	46	4.9
7- Paper	41	4.4
8- Chalk	40	4.3
9- Chalkboard	40	4.3
10- Notes	39	4.2
11- Journals/Articles	35	3.7
12- Overhead projector/Transparencies	32	3.4
13- Copy machine	11	1.2
14- Automobile	7	0.8
15- Photo enlarger and paper	6	0.6
16- TV equipment	5	0.5
17- Forms	5	0.5
18- Department advising guidance sheet	3	0.3
19- Reel and chemicals	3	0.3
20- Calculator	3	0.3

Table 4.25. Results of Subject Work Equipment Usage (continued).
(K Group)

EQUIPMENT USED	SUM COUNT	PERCENT
21- Thesis	3	0.3
22- Soldering Instrument	3	0.3
23- Handout	2	0.2
24- Filing drawer	2	0.2
25- Filing folders	2	0.2
26- Printer	1	0.1
27- Spectrum analyzer	1	0.1

4.4.4 KNOWLEDGE DATA RESULTS

The knowledge data also show some interesting results (Table 4.26 for the B group data, Table 4.27 for the W group data, and Table 4.28 for the K group data). The B group results show a predominance of work knowledge requirements on running the production equipment, quality, and customer specifications, the knowledge requirements here being directly tied to production. The W group results are similar. The K group knowledge is concentrated not so much on the production aspect as in an area of expertise. In the K group, the previous trend of multiplicity is seen again. The variety (breadth) of knowledge requirements is larger than the other groups. It is interesting to note such items as number 28 on Table 4.28 ("past history with alumni"). Here again is another dimension of this type of work (K group) that speaks volumes of this work group. Thus, by scanning the three tables on knowledge data, one gets a picture of the demands on the work groups. This knowledge data, we will see later, may have implications on not only the work analysis and design of these work types, but also in such aspects of human resource management as training and work support mechanisms.

Table 4.26. Results of Subject Work Knowledge Requirements.
(B Group)

KNOWLEDGE REQUIREMENTS	SUM COUNT	PERCENT
1- Run/operate production equipment*	559	54.9
2- Quality	116	11.4
3- Customer specifications	52	5.1
4- Pagemaker software**	49	4.8
5- How to set up or adjust equipment	40	3.9

Table 4.26. Results of Subject Work Knowledge Requirements.
(B Group)

KNOWLEDGE REQUIREMENTS	SUM COUNT	PERCENT
6- Job sequence/Work flow	31	3.1
7- How to lay up job (printing)†	24	2.4
8- Read a blue print	20	2.0
9- Math type software	18	1.8
10- Photoshop software	16	1.6
11- How to run computer	13	1.3
12- Department procedures	12	1.2
13- How to clean equipment	7	0.7
14- How to repair equipment	9	0.9
15- How to program equipment	7	0.7
16- How to make photoplates	6	0.6
17- Safety standards	6	0.6
18- Trouble shoot equipment	5	0.5
19- Scheduling	4	0.4
20- Word software	4	0.4
21- Production materials and requirements	3	0.3
22- How to paste forms	3	0.3
23- Spelling	3	0.3
24- Inventory and shipping information	2	0.2

Table 4.26. Results of Subject Work Knowledge Requirements (Continued).
(B Group)

EQUIPMENT USED	SUM COUNT	PERCENT
25- Hagan system and codes	2	0.2
26- Sound master software	2	0.2
27- How to fold printed materials	1	0.1
28- Make pies	1	0.1

*- A large number of different equipment was listed. In general, the knowledge of how to run/operate the equipment was the crucial knowledge. Since such a large and varied number of operators were used, the type of equipment varied substantially, but the knowledge of "how to operate" was what was essential.
**- Three of the thirty one operators performed production work on a computer for printing, thus the software used to input customer products was essential.
†- This is specific to the printing industry (Print Shop Co.). Several participants listed this as crucial knowledge of their work.

Table 4.27. Results of Subject Work Knowledge Requirements.
(W Group)

KNOWLEDGE REQUIREMENTS	SUM COUNT	PERCENT
1- Word processing software	273	54.3
2- Department policies	46	9.2
3- Graphics software	45	9.0
4- How to use computer	29	5.8
5- Typing skills	21	4.2
6- How to use printer	17	3.4
7- How to use copier	12	2.4
8- Math	9	1.8
9- How to use dictating machine	9	1.8
10- Scheduling	4	1.4
11- Phone numbers (Information)	7	1.4
12- Grammar (text proofing skills)	7	1.4
13- Filing	6	1.2
14- How to use Fax	4	0.8
15- Basic secretarial skills	3	0.6
16- Locations (for scheduling and information)	3	0.6
17- How to use the library	2	0.4
18- Department courses offered	1	0.2
19- Students' advisors	1	0.2
20- Statistics on students	1	0.2

Table 4.28. Results of Subject Work Knowledge Requirements.
(K Group)

KNOWLEDGE REQUIREMENTS	SUM COUNT	PERCENT
1- Area of expertise•	361	51.7
2- Statistics	64	9.2
3- Computer skills	55	7.9
4- Research and research design	47	6.7
5- Fortran	34	4.9
6- Computer software	32	4.6
7- Photography	23	3.3
8- Class, course requirements, and syllabus	13	1.9
9- Administration	10	1.4
10- Teaching	7	1.0
11- University and department policies	7	1.0
12- Mathematics	7	1.0
13- Computer communications package	5	0.7
14- Typing	5	0.7
15- Graphics software	4	0.6
16- Work definitions	3	0.4
17- Adult learning	3	0.4
18- Grammar and punctuation	3	0.4
19- Oklahoma Roads Scholarship Program	3	0.4
20- Group process skills	2	0.3

Table 4.28. Results of Subject Work Knowledge Requirements, (Continued).
(K Group)

KNOWLEDGE REQUIREMENTS	SUM COUNT	PERCENT
21- Teaching assistant assignments	2	0.3
22- Classroom lecture skills	1	0.1
23- Sociology theory	1	0.1
24- Current events	1	0.1
25- Modeling	1	0.1
26- Department course curriculum	1	0.1
27- Honor's Thesis Program	1	0.1
28- Past history with alumni	1	0.1
29- Student's performance	1	0.1
30- How to use library	1	0.1

* The areas of expertise varied since the departments of industrial, mechanical, and electrical engineering were represented in the study. The areas listed were: productivity and quality management, basic industrial engineering, aging, human factors, quality control theory and fundamentals, power engineering, electrical circuits, electrical engineering, mechanical engineering, process and systems engineering, electronics, laser technology, and structural dynamics.

4.5 GENERAL DISCUSSION OF RESULTS

This chapter has covered the primary and secondary data obtained in the field study that was conducted. The work characteristics data (B/W/K work model) were presented (tabulated and graphed) and analyzed statistically. The location, product/service, equipment usage, and knowledge data were also presented and reviewed. In this section these many results, facts and thoughts are brought together. Thus, section 4.5.1 brings together the work characteristics results, and section 4.5.2 the other data results.

4.5.1 DISCUSSION OF WORK CHARACTERISTICS

The work characteristics data analysis results rejected the null hypotheses in all sub-hypotheses (Table 3.2) thus supporting the main hypothesis. Thus, it can be stated that the three types of work (B, W, and K) do not have probability distribution functions that are independent (homogeneous) along the 8 integral work characteristics (outputs, inputs, work type, discretion level, pursuits, endeavors, decision type, and maturity level). The one tailed (2X2) ordered pair analyses (see Table 4.29 below), for the most part, support the skew proposed by the B/W/K work definitions. These results do not, by themselves, validate the work definitions, but do provide a substantial first step in the analysis of this work model.

Table 4.29. Work Characteristics Contingency Table, One Tail (2x2) Analysis Results.

WORK CHARACTERISTIC	ALTERNATIVE HYPOTHESIS *	CHI-SQUARED TEST STATISTIC	p VALUE
1- Output	Pbo<=Pwo	4.588	0.034
	Pwo<=Pko	186.307	<<0.001
2- Input	Pbi<=Pwi	33.623	<<0.001
	Pwi<=Pki	426.112	<<0.001
3- Work Type	Pbwp<=Pwwp	440.403	<<0.001
	Pbws<=Pwws	546.744	<<0.001
	Pbwm>=Pwwm	101.898	<<0.001
	Pwwp<=Pkwp	106.324	<<0.001
	Pwws>=Pkws	66.571	<<0.001
	Pwwm>=Pkwm	272.321	<<0.001
4- Discretion Level	Pbde<=Pwde	318.288	<<0.001
	Pbdf>=Pwdf	474.563	<<0.001
	Pbdh>=Pwdh	61.745	<<0.001
	Pwdl<=Pkdl	255.627	<<0.001
	Pwdf<=Pkdf	2.192	0.1557
	Pwdh>=Pkdh	185.676	<<0.001
5- Pursuit Level	Pbpc<=Pwpc	157.857	<<0.001
	Pbpj<=Pwpj	44.086	<<0.001
	Pbpg<=Pwpg	157.742	<<0.001
	Pbpb>=Pwpb	1.160	0.2204
	Pbpx>=Pwpx	4.769	0.0304
	Pwpc<=Pkpc	250.447	<<0.001
	Pwpj<=Pkpj	43.907	<<0.001
	Pwpg<=Pkpg	9.930	0.002
	Pwpb>=Pkpb	77.873	<<0.001
	Pwpx>=Pkpx	13.814	<<0.001
6- Endeavor	Pbef<=Pwbf	61.732	<<0.001
	Pbeo<=Pweo	148.718	<<0.001
	Pbet>=Pwet	2.912	0.089
	Pbes>=Pwes	0.322	>>0.250
	Pwef<=Pkef	421.448	<<0.001
	Pweo<=Pkeo	26.962	<<0.001
	Pwet>=Pket	188.410	<<0.001
	Pwes>=Pkes	109.128	<<0.001

* The definition of terms for the alternative hypotheses are provided in the list of terms section located in the beginning of this document.

Table 4.29. Work Characteristics Contingency Table One Tail (2x2) Analysis Results. (Continued)

WORK CHARACTERISTIC	ALTERNATIVE HYPOTHESIS	CHI-SQUARED TEST STATISTIC	p VALUE
7- Decision Type	Pbts<=Pwts	146.242	<<0.001
	Pbte<=Pwte	360.444	<<0.001
	Pbtu>=Pwtu	0.215	>>0.250
	Pwts<=Pkts	320.796	<<0.001
	Pwte<=Pkte	181.683	<<0.001
	Pwtu<=Pktu	42.472	0.001
8- Maturity Level	Pbmv<=Pwmv	164.385	<<0.001
	Pbmc<=Pwmc	249.046	<<0.001
	Pbmo>=Pwmo	37.734	<<0.001
	Pwmv<=Pkmv	47.507	<<0.001
	Pwmc<=Pkmc	0.396	>>0.250
	Pwmo>=Pkmo	81.058	<<0.001

4.5.2 DISCUSSION OF OTHER DATA

With respect to the 'other' data (worker location, product/service rendered, equipment usage, and knowledge) several points can be summarized.

1. There is evidence of a difference in worker work mobility, with the K group being the more mobile and the B group the more stationary.

2. The W and K groups were found in work situations at a colleague's office (work location), the K group having the largest percentage of interaction of the two.

3. There seems to exist a larger variety of product/services produced by the K group, with the B group having the least variety.

4. The B group spends longer spans of time on a production entity, while the K group can be characterized as short term by comparison.

5. Equipment usage in the B group is more highly concentrated on a small number of tools. The K group uses the largest variety of tools, but the highest percentage of their time is spent using no tools, while the B group seldom works without the use of some equipment.

6. With respect to work knowledge, the K group requires the most breadth, with the B group having the more concentrated knowledge requirements.

These six points raise many issues.

• Design work environments for the type of work done (B, W, or K) instead of using traditional concepts because they are familiar.

• Account for the work done outside the normal work environment (such as working at home).

• Understand the worker's interactions in his/her work environment.

• Design, foster, and promote work environment interaction.

• Increase the interaction for those groups showing little or no work environment interaction.

• Understand the demands on some work groups with respect to the variety of products/services required of them.

• Design work and provide support mechanisms to assist workers with the demands the work environment may pose.

• Understand the time demands imposed on workers due to the large variety of products and services required of them.

• Understand the demands (training, knowledge, support) of the equipment used by the work force.

• Finally, have a topology of the knowledge requirement demands on each work type or group.

CHAPTER 5

CONCLUSIONS AND IMPLICATIONS OF THIS RESEARCH

In this chapter a further discussion of the results is presented with the intent to go beyond the statistical and factual results and look at some of the more substantive issues raised by this research. This is crucial because it places the results and statistical analysis in the context of the more global question of interest to industrial engineers; what constitutes work? Thus, the research and practical implications of this field study must be addressed.

Figure 5.1 presents the thought diagram that describes the logical development for this chapter. After raising some questions and posing some ideas in section 5.1 (Further Discussion), section 5.2 (what has been learned) follows with the lessons that have been learned from both the work characteristics data, other data (location, product/service, equipment usage, and knowledge), and experience of this study. This leads to section 5.3 where the implications of this research are addressed, specifically, the research implications mainly pertaining to the B/W/K work model. Here, the researcher also presents some notes to future researchers, detailing some of the tacit knowledge and pitfalls encountered. Finally, this research is concluded in section 5.4 where the research inference tree is revisited and re-evaluated. This document ends with the next step to be undertaken by the research agenda initiated by this research.

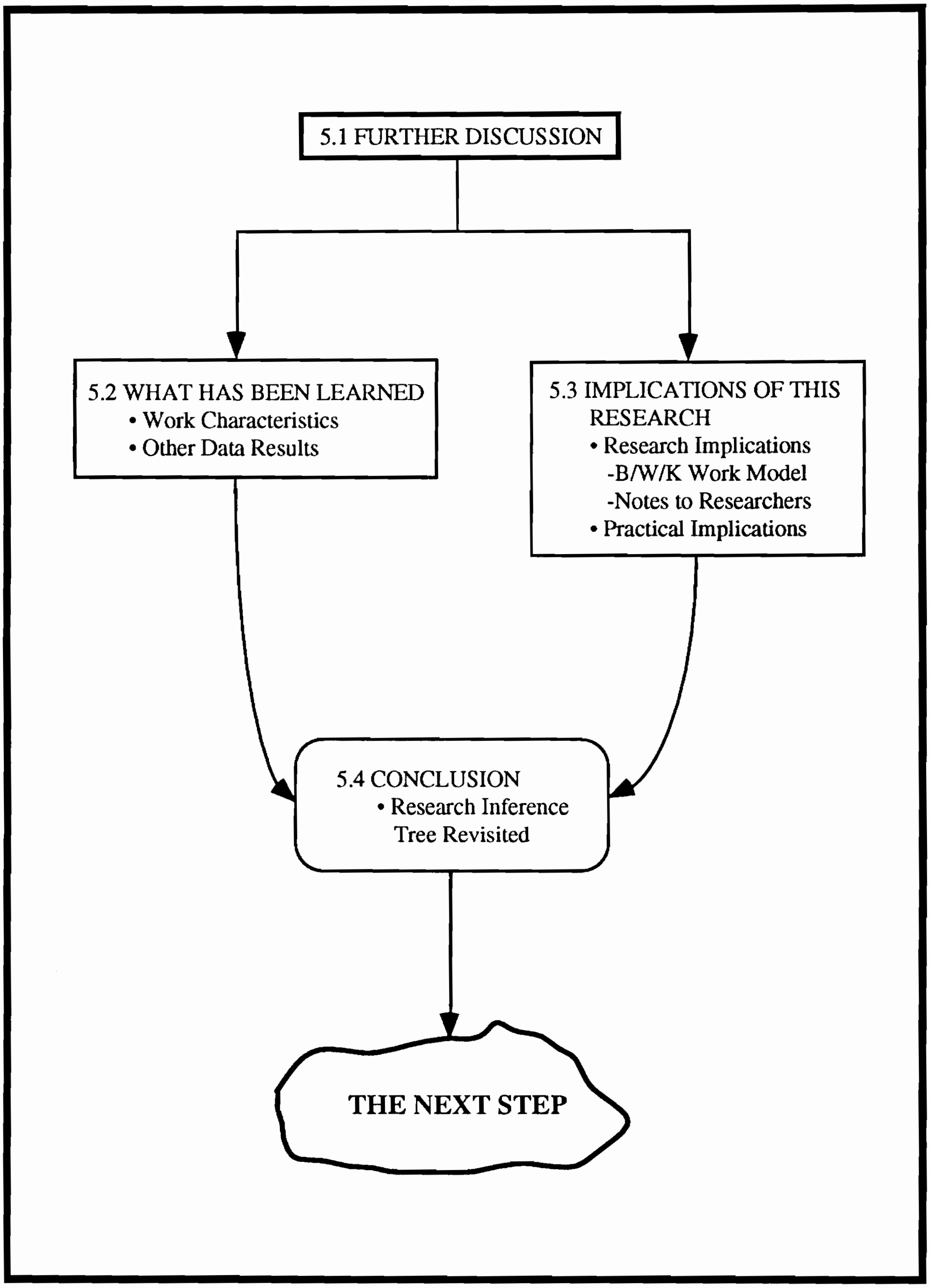

Figure 5.1 Thought Diagram Detailing Logical Development for Chapter 5.

5.1 FURTHER DISCUSSION

At this point, the question that usually comes to mind is, 'What does this all mean?' Thus far, a good number of results, statistics, and inferences have been drawn. Although the amount of data is large and the statistical results substantial, one needs to remember the words of Mark Twain: 'there are lies, damn lies, then there is statistics.' It is essential to question, what is of value here? This being an engineering study, the 'practical' demands recognition. The following sections look at two very specific points; what has been learned? and what are the implications? By doing this, the research here presented attempts to tie together and bring finality to the original question: what constitutes work? Thus, the historical, physical, philosophical, and industrial ideas explored earlier hopefully begin to have a holistic meaning. More importantly, this provides industrial engineers the beginnings of some practical significance with respect to the further study of work.

5.2 WHAT HAS BEEN LEARNED

The lessons of this research are three-fold. Specifically, conclusions can be drawn from the results of the eight work characteristics and the statistical analysis undertaken on the data. Secondly, the worker location, product/services rendered, equipment usage, and knowledge data further enhance our understanding of work and raise questions for further research. Finally, there is the experiential knowledge obtained through having traversed this research with the many observations, problems, disappointments, and successes.

5.2.1 WORK CHARACTERISTIC LESSONS

The work characteristics data and data analysis provide various lessons to the researcher and to those who read this document. First, the B/W/K work definitions have been supported by the results; thus, the research agenda provided in Chapter 2 is initiated. Secondly, some questions have been raised about the classification levels of the eight characteristics (acceptance or rejection of the hypotheses). Specifically, the failure to reject the ordered pair (2x2) analysis on the 'fair' classification of the discretion level characteristic between the W and K groups could have two possible explanations. First, there is no difference between the 'fair' and 'high' classification of the discretion level characteristic, thus reducing the classifications to only two levels (low and high). Secondly, it is possible that university professors (as a population group) have a larger degree of W work characteristics than previously expected (specifically with respect to discretion level), indicating that the discretion level characteristic need not be altered but a more prototypical population should be studied.

With respect to the pursuit level characteristic, failing to reject the 'problem' classification of the ordered pair (2x2) analysis with respect to the B and W groups is possibly a result of the choice of the W group. Initially the W group was going to be supervisory production personnel. No site could be secured to do the study, so the researcher used office and secretarial personnel. It seems reasonable to believe that the original group might have shown a difference along this classification, but this is speculative and should be evaluated. Similarly, the 'tactical' and 'strategic' classifications of the level of endeavor characteristic with respect to the B and W groups failed to reject the ordered pair (2x2) analyses. This again may be a result of the choice of the W group selection for the study. One could speculate that supervisory personnel might show a different data skew than was recorded with the group used.

The failure to reject the null hypothesis with respect to the 'unstructured' classification of the decision type characteristic between the B and W groups is believed to be due possibly to the choice of the W group. The classification (unstuctured decisions) did show significance between the W and K groups, thus strengthening the researcher's belief that the problem is not due to the gradation (structured, semi-structured, and unstructured), but in the prototypicality of the group selected. Finally, the failure to reject the ordered pair (2x2) analysis on the 'control' classification of the maturity level characteristic between the W and K groups is believed to be another indication of the possible higher degree of W type work content in university professor's work than previously believed. This is reinforced by the significance recorded between the B and W groups along the same classification, dispelling the possible conjecture that the maturity level characteristic may only contain two classifications (visibility and optimization).

The results of this study could lead to more concise (operational) definitions of work. The researcher believes that the original work model is still a valid model because the weight of the results (majority) supports the model. The work definitions may need to be altered along some of the work characteristics classifications. It may be a prudent next step to look at studying and evaluating the methodology used in this research. This would prove a vital step for further research with respect to the B/W/K work model. Finally, this study provides a confirmatory study of a conceptual management systems engineering model. The researcher believes that strong, statistically based studies founded on sound industrial engineering practices are an essential part of extending the body of knowledge in this sub-area of industrial engineering.

5.2.2 OTHER DATA RESULTS LESSONS

The location, product/services, equipment usage, and knowledge data provided two major lessons. The data proved to be supportive of the work characteristics. Secondly, the results have raised many questions in the researchers mind and thus stimulated possible research topics for the future. It is believed that requesting information of this nature (not necessarily essential to the study at hand) is a good idea because it provides a more detailed picture of what is being analyzed.

5.2.3 EXPERIMENTAL LESSONS

This study, like all projects that must be managed, provided an invaluable experience to the analyst. To confront the many road blocks, contingencies, and misconceptions is a part of the educational experience that simply can not be taught, but lived. The lesson learned here is that one must live (experience) an endeavor of this nature to understand and value the nature of industrial research.

5.3 IMPLICATIONS OF THIS RESEARCH

In the previous section, the lessons learned from the work characteristics data, the other data results, and the experiential lessons were enumerated. But, what can be drawn from these lessons to thus progress from this research? This section will look specifically at both the research and practical implications of this study. Thus, section 5.3.1 emphasizes the research implications, especially referring back to a re-evaluation of the B/W/K work model and providing notes to future researchers (sub-sections 5.3.1.1 and

5.3.1.2). The practical implications tries to raise some questions as to the way industrial engineers approach, question, analyze, design, and implement work systems.

5.3.1 RESEARCH IMPLICATIONS

An important part of all research are the implications that result from the study undertaken. This section will cover both the research implications of this research as well as some suggestions to future researchers.

5.3.1.1 Re-evaluating the B/W/K Work Model

The B/W/K work model provides a framework for research on work. The results don't indicate an end but an initial condition from which to build. Are there more than eight work characteristics? Is the maturity level characteristic representative of a work characteristic? Most respondents had problems with this characteristic. Are the definitions of the classifications (tangibility, intangibility, process, project, program, etc.) the best possible way to express these terms? Again, this was a concern raised by the study participants. Can these terms be operationally defined? What is implied is that much still needs to be researched in this area. The researcher believes at this time that the eight work characteristics are viable. The 'maturity level' characteristic does show some weakness, but needs further evaluation before being dropped from the model. The work characteristics classification definitions (the definitions for tangibility, intangibility, process, project, program, etc.) do need to be made more 'user friendly' (expressed in laymans terms). In general the B/W/K work model was shown to be a viable model.

5.3.1.2 Notes to Researchers

It is recommended that future researchers consider looking at validating the results obtained here (run a similar study) to see if the same or similar results are obtained. The issues of finding a better training methodology for this research needs to be addressed. It seems that subjects need to be trained in a more formal manner, with specific assignments and testing to see which subjects are in fact prepared to collect data. It is recommended that a better method for data collection be explored to handle the tabulation of the volume of data accumulated. It might be possible to have subjects fill in an opscan like form instead of a check-off sheet as was done in this research study. A better random time generation device could be designed. Such a device was prototyped in the first pilot study conducted by this research, but was not further developed. This could prove to be quite useful for future research attempts. Finally, contingency planning is essential. This research did much to plan for unexpected events, but still was delayed by unforeseen forces.

5.3.2 PRACTICAL IMPLICATIONS

This research has provided a different way in which to do job analysis. The methodology, although imperfect, is still viewed as functional and successful. With some improvements, the methodology could be useful to working engineers, making validation of the research methodology a good next step. The other results raise many questions for practicing industrial engineers. First, do we understand the work of mainly W and K work groups and individuals? Do we design work environments, work tasks, and work flows for mainly W and K work groups and individuals with a Tayloristic (mainly B work) conception of work? Have we addressed the issue of equipment usage adequately for mainly W and K work? The results obtained by this study raise some practical questions for industrial engineers.

5.4 CONCLUSION

The confirmatory study documented in these pages addressed the concerns raised early on in this text. The data show some promising results with respect to the work definitions postulated. Additionally, other questions have been raised that are a positive by-product of any research effort. How has the research agenda presented in this document been affected by the results obtained? This is addressed next.

5.4.1 RESEARCH INFERENCE TREE REVISITED

The research agenda (inference tree) presented in Chapter 2, Figure 2.12, is believed to be supported by this research. The only alteration plausible at this time is to investigate (validate) the research methodology before proceeding with other inference tree items. This is recommended because it seems a sound idea to validate the tool used to gather data in this type of research since it is the foundation for future research ventures on the inference tree.

5.4.2 THE NEXT STEP

In conclusion, there are three steps envisioned that should be addressed by the researcher as a result of this specific research. First, evaluate the field methodology employed in this research. Secondly, re-run the study (with the validated and possibly re-designed methodology and training) to further strengthen the validity of the results (as mentioned above). Finally, it would be a good idea to detail the work definitions further so as to obtain more operational definitions.

REFERENCES

Achabal, D. D., Heineke, J. M. and McIntyre, S. H. (1985). "Productivity measurement and the output of retailing," Journal of Retailing, Fall, pp. 83-88.

Ackoff, R. (1967). "Management misinformation systems," Management Science, vol. 11, no. 4, pp. B147-B156.

Albrecht, A. J. (1985). "Functions points helps managers assess implications, maintenance values," Computer World, August, pp. 50-51.

Allen, P. (1981). "Managers at work: A large-scale study of the managerial job New York City government, Academy of Management Journal, vol. 24, pp. 613-619.

Allen, L. E. (1986). "Measuring productivity in the automated office," Administrative Management, December, pp. 41-43.

American Sociological Association (1989). Footnotes, March, vol. 10, pp. 9-10.

Ansberry, C. (1992). "The genteel poor," Wall Street Journal, February 10, pp. A1, A7.

Anthony, M. G. (1984). "IEs measure work, write standards for white collar workers at financial institution," Industrial Engineering, January, pp. 197-200.

Anthony, R. N. (1965). Planning and control systems, A framework for analysis, Division of Research, Graduate School of Business Administration, Harvard University, Boston.

APA (1992). "Ethical principles of psychologists and code of conduct," American Psychological Association, Washington, D. C., 15p.

Arandt, H. (1958). The human condition, University of Chicago Press, Chicago Illionois.

Armentrout, D. R. (1986). "Engineering productivity management and performance measurement," Journal of Management Engineering, December, pp. 141-147.

Ashkenas, R. N. and Schaffer, R. H. (1984). "Time: managers can avoid wasting it," Working Woman, January, pp. 38-43.

BAI/APC (Bank Administration Institute/American Productivity Center) (1984). "Joint venture takes hard look at bank productivity," Computer World, May 28, p. 37.

Baker, S., D. Woodruff, and E. Weiner (1992). "Detroit south, Mexico's auto boom: Who wins, who looses," Business Week, March 16, pp. 98-102.

Baker, T. L. (1988). "Varieties of social-scientific research," in Doing social research, McGraw-Hill, Inc., New York, pp. 15-18.

Bancroft, N., and Sontag, B. (1984-85). "Productivity improvement in the office at Digital Equipment Corporation," National Productivity Review, Winter, pp. 53-59.

Barnes, R. M. (1980). Motion and time study: Design and measurement of work, 7th ed., John Wiley & Sons, New York.

Batson, R. G. and Miller D. (1985). "Objectives setting is efficient tool for R&D annual planning," Industrial Engineering, August, pp. 36-46.

Baumgardner, M. (1981). "Productivity improvement for office systems," Journal of Systems Management, August, pp. 12-14.

Beruvides, M. G. and C. P. Koelling (1992a). "Management tools: A technological issue in white-collar/Knowledge work," in T. M. Khalil and B. A. Bayraktar (eds.) Management of technology III, Industrial Engineering and Management Press, Norcross, Georgia, pp. 1357 - 1363.

Beruvides, M. G. and C. P. Koelling (1992b). "Technology space mapping of tools: A management issue in understanding work," Working Paper, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. Submitted to Proceedings of the International Conference of Productivity and Quality Research.

Beruvides, M. G. and C. P. Koelling (1992c). "Faculty work: A pilot study," Virginia Tech Industrial & Systems Engineering Reprint Series Paper No. 9208, December, 8, Blacksburg, Virginia,, 13p.

Beruvides, M. G., Omachonu, V. K., and Sumanth, D. J. (1988), "A conceptual framework of work: The measurement of white collar / knowledge productivity," in D. J. Sumanth et. al. (eds.) Productivity Management Frontiers - II, Geneva, Inderscience Enterprises LTD, pp. 39 - 46.

Beruvides, M. G., and Sumanth D. J. (1987). "Knowledge work: a conceptual analysis and structure," Productivity Management Frontiers - I, February, pp.127-138.

Beruvides, M. G., Omachonu, V. K., and Sumanth D. J. (1989). "A conceptual framework of work: the measurement of white collar/knowledge work productivity," Productivity Management Frontiers - II, February, p. 39.

Bishop, T., (1987). "Staff development: A collaborative planning model," Thrust, vol. 16, no. 4, pp. 46 - 48.

Bobbe, R. a. and Schaffer, R. H. (1983). "Productivity improvement: manage it or buy it?' Business Horizons, March/April, pp. 62-69.

Bocazany, W. J. (1985). "Productivity improvement making work fun," Journal of Systems Managements, April.

Bolte, K. A. (1983-84). "Intels war for white collar productivity," National Productivity Review, pp. 46-53.

Bolte, K. A. (1984). "Intel's six steps to a $17-million savings in white collar productivity," Management Review, December, pp. 52-54.

Bowen, W. (1986). "The puny payoff from office computers," Fortune, May 26.

Brennam, R. J. (1992). "Union ratifies Conrail contract to reduce crews," Wall Street Journal, February 7, p. A6.

Brinberg, D. and J. E. MacGrath (1985). Validity and the research process, Sage Publications Inc., Newbury Park, California.

Brisley, C. L. and Fielder. W. (1983). "Undermeasurable output of knowledge/office workers can and must be measured," Industrial Engineering, July, pp. 108-110.

Broawell, M. M. (1965). "The relationship between the engineer's productivity, satisfaction and ability, or: P=f(DS) + A", IEEE Transactions on Engineering Management, December, pp. 150-153.

Brown, J. (1984). "Office productivity: a people challenge, not a technology solution," Business Quarterly, Summer, pp. 55-58.

Buckwalter, N. (1984). "White collar productivity," United States Banker, November, pp. 40-42.

Business Week, (1992). "Free trade with Mexico: gain, pain, retrain," March 16, p. 138.

Calmes, R. A. (1981). "Career planning and performance appraisal techniques for improving salaried employee productivity," Institute of Industrial Engineers Fall Conference Proceedings, pp. 29-34.

Camp, L. G. (1985). "IE's evaluate productivity improvement efforts in our organizations and across US," Industrial Engineering, pp. 80-85.

Cannon, B. W. (1979). "New frontier in productivity improvement: white collar workers," Industrial Engineering, December, pp. 34-37.

Carlyle, E. R. (1985). "Building a better programmer," Datamation, October, pp.42-44.

Cerveny, R. P. and Saunders, G. L. (1985). "Office management: increasing productivity in the workplace," Healthcare Financial Management, June, pp. 60-64.

Champanis, A., (1988). "Some generalizations about generalization," Human Factors, vol. 30, no. 3, pp. 253 - 267.

Chaneski, W. S. (1985). "Managing people effectively: how to get the best performance from employees," Industrial Engineering, pp. 31-34.

Chippello, C. J. and N. Templin (1992). "Work ethic aside, some U. S. employees still live very well: Alook at families in Detroit, Toyota City shows how Americans stay ahead," Wall Street Journal, February 24, pp. A1, A10.

Christopher, W. F. (1984). "How to measure and improve productivity in professional, administrative, and service organizations," 1984 Annual International Industrial Engineering Conference Proceedings, pp. 64-71.

Cochran, W. G. (1977). Sampling techniques, 3rd edition, John Wiley & Sons, New York.

Cochran, W. G. (1968). "The effectiveness of adjustment by subclassification in removing bias in observational studies," Biometrics, vol. 24, no. 2, pp. 295-313.

Cochran, W. G. (1954). "Some methods for strengthening the common x^2 tests," Biometrics, vol. 10, no. 4, pp. 417-451.

Cochran, W. G. (1952). The x^2 test of goodness of fit," The Annals of Mathematical Satistics, vol. 23, pp. 315-345.

Conn, H. P. (1984). "Improving use of discretionary time raises productivity of knowledge workers in offices," Industrial Engineering, July, pp. 70-77.

Conover, W. J. (1971). Practical nonparametric statistics, John Wiley & Sons, Inc., New York.

Curley, K. F. and Pyburn, P. J. (1982). "'Intellectual' technologies: the key to improving white collar productivity," Sloan Management Review, Fall, pp. 31-39.

Cushnie, J. A. (1987). "Measuring knowledge work - 'How to'," Productivity Management Frontiers - I, February, pp. 147-154.

Daniels, A. C. (1985). "Performance management: the behavioral approach to productivity improvement," National Productivity Review, Summer, pp. 225-236.

Danzinger, J. N. and Kraemer, K. L. (1985). "Computerized data-based systems and productivity among professional workers: The case of detectives," Public Administration Review, January/February, pp. 196-209.

Davis, B. and D. Milbank (1992). "If the U. S. work ethic is fading, alienation may be main reason," Wall Street Journal, February 7, pp. A1, A4.

Deming, W. E., (1986). Out of the Crisis, MIT Press, Cambridge, Massachussets.

Deveny, K. (1992). "AT&T unionist seeks greater role in management," Wall Street Journal, February 26, A6.

de Wet, G. (1992). "Technology space maps for technology management and audits," in T. M. Khalil and B. A. Bayraktar (eds.) Management of Technology III, Norcross, Georgia, Industrial Engineering and Management Press, pp. 1235 - 1243.

Dewitt, F. (1986). "Productivity and the industrial engineer," Industrial Engineering, January, pp. 20-27.

Dickinson, R. M. (1984). "Office productivity can be measured," Computer Decisions, July, p. 74.

Doering, R. D. (1973). "Technical management notes," IEEE Transactions on Engineering Management, February, pp. 29-31.

Dougherty, W. H. (1983). "Greater productivity is service industry's aim," The Office, March, pp. 144-145.

Douglas, M. and Douglas, D. (1982). "Improve white-collar productivity," Personnel Administrator, December.

Drucker, D. F. (1974). Management: Task, Responsabilities, Practices, Harper & Rows, New York.

Drummond, S. (1985). "Measuring applications development performance," Datamation, February, pp. 102-108.

Edelman, F. (1982). "Managers, computer systems, and productivity," Interfaces, October, pp. 35-46.

Ferguson, T. W. (1992). "Tales of the CAT and GM, joined by a Union," Wall Street Journal, April 14, p. A19.

Filley, R. D. (1984). "What's holding IE's back from the office of the future?" Industrial Engineering, December, pp. 38-45.

Finley, J. (1991). "Boosting productivity at American Express," Business Week, October 5, pp. 65-66.

Fischer, W. A. and Mc Laughlin, C. P. (1980) "MBO and R&D productivity: revising the systems dynamics," IEEE Transactions on Engineering Management, November, pp. 103-108.

Fitz, J. (1986). "White-collar effectiveness, Part I: the employees' side," Management Review, May.

Fitz, J. (1986). "White-collar effectiveness, Part II: the organization side," Management Review, June.

Ford, R. J. (1985). "New approaches to improve white collar productivity," Industrial Engineering, August, pp. 48-53.

Forrester, J. W. (1961). Industrial dynamics, MIT Press, Cambridge, Massachusetts.

Frazalle, E. and Smith, C. (1985). "Productivity improvement through office-space planning," National Productivity Review, Summer, pp. 265-274.

Frazalle, E. and Smith, C. (1984). "Worker participation in office-space planning and design process pays larger dividends," Industrial Engineering, December, pp. 34-37.

Fromm, E. (1991). Marx's concept of man, Continuum Publishing Co., New York.

Gery, G. J. (1982). "Office technology: creating receptivity among executives and professionals," National Productivity Review, Spring, pp. 202-213.

Gilbreth, F. B. (1914). Primer to scientific management, D. Van Nostrand Co., Princeton, New Jersey.

Gilbreth, F. B. (1911). Motion study, D. Van Nostrand Co., Princeton, New Jersey.

Gilbreth, F. B. (1909). Bricklaying system, Myron C. Clarck Publishing Co., New York.

Gilbreth, F. B. and L. M. Gilbreth (1919). Fatigue study, 2nd ed., Macmillan Co., New York.

Gilbreth, F. B. and L. M. Gilbreth (1917). Applied motion study, Sturgis & Walton Co., New York.

Gilbreth, L. M. (1914). The psychology of management, Sturgis & Walton Co., New York.Holman, J. P. (1976).

Goldberg, A. I. and Shenhav, Y. A. (1984). "R&D career paths: their relation to work goals and productivity," IEEE Transactions on Engineering Management, Vol. 31, No. 3, pp. 111-117.

Goldberg, J. A. (1985). "Management style: a catalyst to productivity improvement in the public sector," National Productivity Review, Autumn, pp. 416-418.

Goldfield, R. J. (1983). "Achieving greater white-collar productivity in the new office, Byte, May.

Goldstein, M. H. (1983). " Office automation and executive productivity, " National Productivity Review, Autumn, pp. 426-429.

Goodman, P. S. Rose, J. H., and Furcon, J. E. (1970). "Comparison of motivational antecedents of the work performance of scientists and engineers," Journal of Applied Psychology, Autumn, pp. 491-495.

Gorry, G. A. and M. S. Scott Morton (1971). "A framework for management information systems," Sloan Management Review, Fall.

Grahn, J. L. (1981). "White collar productivity: misunderstandings and some progress," Personnel Administrator, August.

Greenberg, E. R. (1986). "Measuring white-collar productivity," Management Review, September.

Greenwood, F. and Greenwood, M. (1984). "Productivity brief," Journal of Systems Management, November.

Gregerman, I. B. (1981). Knowledge Worker Productivity, Amacon Press,New York.

Guest, R. H. (1956). "Time and the Forman," Personnel, vol. 32, pp. 478-486.

Hamann, J. (1986). "Getting more out put from your department," Management Solutions, August.

Heller, F. A. (1969). "The managerial role on the effective use of resources," Journal of Management Studies, February, pp. 1-14.

Heshizer, B. and Graham, H. (1984). "Justice without juries," Management World, March.

Higgins, B. and Dice, c. M. (1984). "Quantifying white collar functions," National Productivity Review, Summer, pp. 288-302.

Hill, S. C. (1970). "A natural experience on the influence of leadership and behavior patterns on scientific productivity," IEEE Transactions on Engineering Management, February, pp. 10-19.

Hoffman, J. J. Jr. and Hobson, C. J. (1984). "Physical fitness and employee effectiveness," Personnel Administrator, April, pp. 101-113.

Holman, J. P. (1976). Heat transfer, 4th ed., McGraw-Hill Book Co., New York.

Holzman, A. G. (1976). "Productivity in IE education," Industrial Engineering, February, pp. 30-32.

Hoop, C. C. and Wolzansky, J. N. (1983). "Matching white-collar skills to the work," Harvard Business Review, November/December.

Horowitz, T. (1992). "Working class culture erodes Britain's rank in a unified Europe," Wall Street Journal, February 11, pp. A1, A10.

Howard, N. and Teramoto, Y. (1981). "The really important difference between Japanese and Western management," IEEE Transactions on Engineering Management, Fall, pp. 19-29.

Hudson, J. D. (1983). "Office technology turning promises into gains," National Productivity Review, Summer, pp. 257-265.

Hulbert, H. M. and Scalera, M. (1967). "A model for corporate growth by new product research productivity," IEEE Transactions on Engineering Management, June, pp. 83-88.

Huling, J. (1985). "Manager's role critical to keeping staff productive," Computer World, August, pp. 19-20.

Inmon, W. (1984). "Rethinking productivity," Datamation, June, pp. 185-188.

Iseberg, D. J. (1984). "How senior managers think," Harvard Business Review, November/December, pp. 81-90.

Jacobs, B. A. (1984). "Designing offices that work," Industry Week, February 6.

Jamali, S. (1983). "Putting a productivity improvement plan into action: A six step plan," Industrial Engineering, February, pp. 68-78.

Jenkins, A., Jr. (1984). "LAN is the answer to white-collar productivity," Data Management, August.

Jenster, V. (1986). "Firm information and monitoring of critical success factors in different strategic contexts." Journal of Management Information, Winter, pp. 17 - 33.

Johnson, W. B. (1991). "Global work force 2000: The new world labor market," Harvard Business Review, vol. 69, no. 2, pp. 115 - 127.

Jones, B. M. (1982). "Higher programmer productivity through better communications," The Bankers' Magazine, May/June, pp. 36-39.

Judson, A. S. and Carillo, F. J. (1983). "Building on success: managing productivity improvement by strategy," National Productivity Review, Autumn, pp. 347-361.

Keller, J. J. (1992). "AT&T will cut managers posts of 2000 workers," Wall Street Journal, February 7, p. A7.

Keller, R. T. and Holland, W. F. (1982) "The measurement of performance among research and development professional employees: A longitudinal analysis," IEEE Transactions on Engineering Management, May, pp. 54-57.

Kelliger, M. E. (1985). "Managing productivity performance and the cost of services," Healthcare Financial Management, September, pp. 23-27.

Kelly, K. (1992). "This brawl could cost CAT a couple of its lives," Business Week, March, 23, pp. 82 - 83.

Kendrick, J. W. and D. Creamer (1965). Measuring company productivity: Handbook with case studies, Studies in Business Economics, No. 89, National Industrial Conference Board, New York.

Kerlinger, F. N. (1986). Foundations of behavioral research, Holt, Rinehart & Winston, New York.

Kish, J. L. (1982). "Auditing word-processing productivity and performance," National Productivity Review, Autumn, pp. 427-436.

Kozlowski, S. W. J. and Hults, B. m. (1986). "Joint moderation of the relationship between task complexity and job performance for engineers," Journal of Applied Psychology, pp. 196-201.

Kranzberg, M. (1959). "At the start," Technology and Culture, vol. 1, no. 1, pp. 1-10.

Kristakis, J. (1983). "Short method makes frequent evaluation of office productivity a realistic objective," Industrial Engineering, December, pp. 113-115.

Kurke, L. B. and H. E. Aldrich (1983). "Mintzberg was right: A replication and extension of the nature of managerial work," Management Science, vol. 29, no. 8, pp. 975-984.

Kurstedt, H. A., (1991). The student guide to the research process, Working papers, Management Systems Laboratory, Virginia Tech, Blacksburg, VA.

Kurstedt, H. A. (1990a). Management Systems Theory, Applications, and Design, Vol. 1, Working Papers, Management Systems Laboratory, Virginia Tech, Blacksburg, VA.

Kurstedt, H. A. (1990b). Management Systems Theory, Applications, and Design, Vol. 2, Working Papers, Management Systems Laboratory, Virginia Tech, Blacksburg, VA.

Kuzela, L. (1984). "White-collar automation 'statistical technique to boost performance,'" Industry Week, November 12.

Kuzela, L. (1987). "Japanese target offices 'exactly what they did in manufacturing,'" Industry Week, June 29.

Lambert, R. (1983). "Productivity awareness at Manufacturers Hanover Trust," National Productivity Review, Summer, pp. 298-306.

Larson, R. W. and Fielden, J. S. (1985). "The managerial clerk syndrome," Business Horizons, January/February.

Leedy, P. D. (1989). Practical research: Planning and design, MacMillan Publishing Co., New York.

Lehrer, R. N. (1983). White Collar Productivity, New York: McGraw-Hill.

Lemos, R. M. (1986). Rights, goods, and democracy, University of Delaware Press, Newark.

LeVeau, B. (1977). Williams and Lissner: Biomechanics of human motion, 2nd ed., W. B. Saunders Co., Philadelphia.

Light, R. J. J. D. Singer, and J. B. Wilett (1990). By design, Harvard University Press, Cambridge, Massachussetts.

Liker, J. K. and Hancock, W. M. (1984). "Work environment survey generates ideas on increasing white collar productivity," Industrial Engineering, July, pp. 60-69.

Locke, J. (1952). The second treatise of government, Bobbs-Merrill Co., New York.

Lublin, J. S. (1992). "Seeking wisdom of seasoned veterans, more firms rehire departed executives," Wall Street Journal, April 29, pp. B1, B12.

Luthi, H. KJ and Plymeris, A. (1985). "Scheduling to minimize maximum workload," Management Science, November, pp. 1409-1415.

Maas, M. (1983). " In offices of the future ... the productivity value of environment," Management Review, March, pp. 16-20.

Machalaba, D. (1992). "CSX bids to reduce train crews wins Union ratification," Wall Street Journal, April 21, p. A4.

Macintosh, N. B. (1981). "A conceptual model of information systems," Accountiong, Organizations and Society, (England), vol. 6, no. 1, pp. 35-52.

Magnolia-Zoch, D. and Weiner, R. G. (1984). "Plan applies IE concepts to improve productivity and measure creative process of professionals," Industrial Engineering, September, pp. 46-53.

Maier, N. R. F. (1965). Psychology in industry, Houghton Mifflin Co., Boston, Massachusets.

Major, M. J. (1984). "The quality measure of white collar productivity," Modern Office Technology, October, pp. 160-166.

Mandakovic, T. and Souder, W. E. (1987). "A model for measuring R&D productivity," Productivity Management Frontiers - I, January, pp. 139-146.

Marks, W. W. and Strawbridge, W. D. (1985). "Well-honed management techniques will give boost to data processing center productivity," Computer World, August, pp. 16-17.

Martin, K. R. (1977). "Don't overlook clerical productivity," Industrial Engineering, February, pp. 28-33.

Martin, P. and Nicholls, J. (1985). "How to manage commitment," Management Today, April, pp. 56-57, 107-112.

Marx, K. (1844). Economic and philosophical manuscripts, in E. Fromm's Marx's concept of man, Continuum Publishing Co., New York.

Mazzola, P. and Kauffman, J. D. (1978). "Activity measurement program promotes productivity," Industrial Engineering, June, pp. 26-31.

McCormick, E. J. and M. S. Sanders (1982). Human factors in engineering and design, 5th ed., McGraw-Hill Book Co., New York.

McGee, J. P. and R. L. Welsh (1982). "The need to redirect industrial engineering toward office productivity," Proceedings of Institute of Industrial Engineers Annual Conference, pp. 361-367.

Menkus, B. (1985). "Office air quality and productivity," Administrative Management, October, p. 83.

Metzger, R. O. (1982-1983). "Banking in the 1980s: productivity improvement on an experimental curve," National Productivity Review, Winter, pp. 22-28.

Metzger, R. O. (1981). "Productivity in banking - and how to improve it," The Bankers' Magazine, May/June, pp. pp. 52-58.

Meyer, N. D. (1982-83). "The relationship between office automation and productivity," National Productivity Review, Winter, pp. 79-81.

Mintzberg, H. (1980). "Structure in 5's: A synthesis of the research on organization design," Management Science, vol. 26, no. 3, pp. 322-341.

Mitchell, J. and N. Templin (1992). "GM idles plant in Oklahoma; Talks heat up," Wall Street Journal, September 3, p. A3.

Milbank, D. (1992). "The modern Okies: Industrial Migrants scour U. S. for work, with dwindling luck," Wall Street Journal, March 2, pp. A1, A4.

Miller, D. M. (1984). "Profitability = Productivity + Price Recovery," Harvard Business Review, May/June, pp. 145-153.

Miller, J. P. (1992). "Caterpillar's principle engine factory is struck by UAW as walkout escalates," Wall Street Journal, February 24, p. A16.

Minkes, A. L., (1987). "Decision assembly lines," Across the Board, vol. 24, no. 10, pp. 47 - 50.

Mintzberg, H. (1975). "The manager's job: Folklore and fact," Harvard Business Review, vol. 53, no. 4, pp. 49-61.

Mintzberg, H. (1973). The nature of managerial work, Harper and Row, New York.

Mooney, M. (1982). "Organizing for productivity management," National Productivity Review, Spring, pp. 141-150.

Morganthaler, E. (1992). "The work ethic is a living thing to the Morgans," Wall Street Journal, February 26, pp. A1, A6.

Morris, W. T. (1979). Implementation strategies for industrial engineers, Columbus, Ohio, Grid Publishers.

Mundel, M. E. (1983). "Wanted: A system that provides 'Box scores for productivity,'" Industrial Engineering, October, pp. 74-81.

Mundel, M. E. (1978). Measuring and Enhancing the Productivity of service and Government Organizations, Hong Kong: Asian Productivity Organization.

Nadler, G. (1963). Work design, Richard D. Irwin, Inc., Homewood, Illinois.

Nag, D. (1989). An analytical approach for the measurement of White-collar/Knowledge worker productivity in organizations, Masters Thesis, University of Miami, Coral Gables, Florida, 137p.

Nagaprasanna, B. R. (1980). " IE methods boost airline productivity, resulting in cost savings," Industrial Engineering, April, pp. 24-26.

Niebel, B. W. (1988). Motion and time study, 8th ed., Irwin, Homewood, Illinois.

Nussbaum, B., A. T. Palmer, A. Z. Cuneo, and B. Carlson (1992). "Downward mobility," Business Week, March 23, pp. 56-63.

Olsen, C. W. (1985a). "Managing for productivity," Machine Design, May, pp. 94-97.

Olsen, C. W. (1985b). "Managing for productivity," Machine Design, June, pp. 66-69.

Olson, V. (1983). "The search for the productivity grail: the 4/8 theory," Supervisory Management, December.

Ozatalay, S. and Reilly, B. J. (1990) "The human aspect of technological revolution," Management of Technology II, Norcross, Georgia, Industrial Engineering and Management Press, pp. 749 - 757.

Packer, M. D. (1983a). "analysing productivity in R & D organizations," Research Management, January-February, pp. 13-20.

Packer, M. D. (1983b). "Measuring the intangible productivity," Technology Review, February/March, pp. 48-57.

Patterson, G. A. (1992). "How GM's car plant in Arlington, Texas, hustled to avoid ax: Workers offered flexibility such as a 3-shift system, bypassing UAW bosses," Wall Street Journal, March 6, pp. A1, A4.

Patterson G. A. and R. L. Rose (1992). "Labor makes a stand in fight for its future at Caterpillar Inc.: Right to hire replacements is an issue - at company, in Congress, in campaign," Wall Street Journal, April 7, pp. A1, A8.

Patton, J. A. (1982). "Managers and productivity ... no one to blame but themselves?" Management Review, October, pp. 13-18.

Patton, M. Q. (1990). Qualitative evaluation and research methods, 2nd edition, Sage Publications Inc., Newbury Park, California.

Pearl, D. (1992). "The upwardly mobile find hopes dashed on suburban plateaus," Wall Street Journal, March 30, pp. A1, A5.

Peregoy, R. P. and Alonso, A. (1979). "What about productivity improvement in the community?" Industrial Engineering, May, pp. 30-31.

Peregoy, R. P. and Humphries, B. R. (1981). "Determining the productivity of office automation at Florida Power and Light Company," Productivity Management Frontiers - I, February, pp. 203-216.

Peterson, R. E. (1977). "The components of information," Interfaces, vol. 7, no. 4, pp. 87-91.

Platt, J. R., (1964). "Strong inference," Science, no. 146, pp. 347 - 353.

Ponder, Q. D. (1957). "The effective manufacturing foreman," in E. Young (ed.), Industrial Relations Association Proceedings of the Tenth Annual Meeting, Madison, Wisconsin, pp. 41-54.

Porter, A. L. (1984). "Work issues raised by office automation call for expertise of industrial engineers," Industrial Engineering, December, pp. 25-32.

Quinn, M. P. and Bhatty, E. F. (1984). "Cost of quality and productivity improvement," 1984 Annual International Industrial Engineering Conferences Proceedings, pp. 157-165.

Rainy, G. W. and Wolf, L. (1982). "The organizationally dysfunctional consequences of flexible work hours: A general overview," Public Personnel Management Journal, Summer, pp. 165-174.

Ranftl, R. M. (1984). "Training managers for high productivity: the Hughes approach," National Productivity Review, Spring pp. 170-180.

Richards, R. (1984). "White-collar quality circles and productivity," Training and Development Journal, October.

Robinson, B. (1983). "A new approach to increasing organizational commitment and productivity - the management planning and performance appraisal system," Training and Development Journal, January, pp. 58-61.

Rockhold, A. G. (1982). "White collar productivity," Infosystems, April, pp. 58-64.

Root, L. J. M. (1984). "IE's should examine impact of management style on motivation and productivity," Industrial Engineering, January, pp. 6-7.

Rose, R. L. (1991). "Caterpillar strike is a big risk for UAW: Union pins industry bargaining power on effort," Wall Street Journal, December 27, p. A2.

Rose, R. L. (1992). "Caterpillar Inc. pledges it won't yield in UAW strike; Union vows to fight back on," Wall Street Journal, March 30, p. B12A.

Rose, R. L. and G. A. Patterson (1992a). "Caterpillar chairman and strike leader share one common trait: Stubbornness," Wall Street Journal, April 10, p. B6.

Rose, R. L. and G. A. Patterson (1992b). "Caterpillar Inc. threatens to replace UAW strikers: Union responds with call to expand its walkout as stakes in battle rise," Wall Street Journal, April 2, p. A3.

Rosenberg, J. C. (1983). "Cost-effective patient care: Harper-Grace Hospitals," Industrial Engineering, January, pp. 48-51.

Rowe, D. 1. (1981). "How Westinghouse measures white collar productivity," Management Review, November.

Ruch, W. A. (1982). "The measurement of white collar productivity," National Productivity Review, Autumn, pp. 416-42.

Ruch, W. A. (1980). "Knowledge worker productivity," Manufacturing Productivity Frontiers, August, pp. 11-14.

Ruiz-Quintanilla, S. A. and B. Wilpert (1988). "The meaning of work - Scientific status of a concept," in V. de Keyser, T. Ovale, B. Wilpert, and S. A. Ruiz-Quintanilla (eds.), The meaning of work and technological options, John Wiley & Sons, Chichester, England, pp. 3 - 14.

Satterfield, D. and DeGeorge, G. (1986). "Managing productivity," The Miami Herald, March, PP. 1, 12-13.

Schlesinger, J. M. (1992). "A U. S. professor takes an unusual course in a Japanese factory," Wall Street Journal, March 30, pp. A1, A7.

Schroeder, R. G., Anderson, J. C. and Scudder, G. D. (1986). "White collar productivity management," Management Decission, Winter.

Sears, F. W., M. W. Zemansky, and H. D. Young (1977). University Physics, 5th ed., Addison-Wesley Publishing Co., Reading, Massachusetts.

Semich, J. W. (1986). "Our real competitive problem: Unproductive management," Purchasing, January 30.

Shapira, Z. and R. L. M. Dunbar (1980). "Testing Mintzberg's managerial roles: Classification using an in-basket simulation," Journal of Applied Psychology, vol. 65, pp, 87-95.

Shell, R. L., Okagbau, O. G. and Huston, T. R. (1985). "The work station of the future for knowledge workers," Industrial Engineering, August, pp. 54-62.

Simon, H. A. (1977). The new science of management decision, 3rd ed., (first published in 1960), Prentice-Hall, Englewood Cliffs, New Jersey.

Sink, D. S. (1990). "Developing measurement systems for world class competition," Working Paper, Virginia Productivity Center, Virginia Tech, Blacksburg, VA.

Sink, D. S. (1985). Productivity management: Productivity measurement, evaluation, control and improvement, John Wiley & Sons, New York.

Sink, D. S., Das, S. K. and Tutle, T. C. (1987). "Measuring and improving 'white collar' productivity: A NASA case study," Productivity Management Frontiers - I, February, pp. 155-163.

Sink, D. S., P. E. Rossler and Dhir, A. K. (1987). "An update on the study of productivity measurement and incentive methodology," Productivity Management Frontiers - I, February, pp. 165-175.

Sink, D. S., T. C. Tuttle, and S. J. DeVries (1984). Productivity measurement and evaluation: What is available?," National Productivity Review, Summer, pp. 265-287.

Sink, D. S. and T. C. Tuttle, (1989). Planning and Measurement in Your Organization of the Future, Industrial Engineering and Management Press, Norcross, Georgia.

Skinner, B. F., (1985). "What is wrong with daily life in the Western World?" Paper presented to the American Psychological Association, August, pp. 15 - 31.

Skinner, B. F., (1982). "Why we are not acting to save the world," Paper presented to American Psychological Association, Aug. pp. 1-4.

Slaughter, G. (1982). "The team approach to DP productivity," Data Management, August, pp. 28A-28L.

Smith C. (1984). "Awareness, analysis and improvement are keys to white collar productivity," Industrial Engineering, January, pp. 8-11.

Smith, C. T. Jr. (1984). "A holistic approach to white-collar productivity," The Office, January.

Soncini, R. A. (1983). "Raising clerical productivity with most clerical computer systems," Industrial Management, September/October, pp. 172-175.

Staff Report (7) (1983). "Measuring executive productivity: a nice idea, but can it be done?" Office Administration and Automation, August, p. 7.

Staff Report (6) (1983). "Enhancing programmer productivity," Electronics, September, p. 115.

Staff Report (5) (1983). "Do you underestimate your secretary?" Computer Decisions, September, pp. 70-71.

Staff Report (4) (1984). "Management functions perceived to affect productivity the most," Industrial Engineering, January, p. 6.

Staff Report (3) (1985). "how to raise white collar productivity," Industry Distribution, May.

Staff Report (2) (1986). "Is American business being damaged to death?" The Economist, December 13.

Staff Report (1) (1986). "Office automation advances 'white collar' productivity," Dun's Business Month, March.

Stahl, M. J., McNichols, C. W. and Manly, T. R. (1979). "Cosmopolitan - local orientations as predictors of scientific productivity, organizational productivity, and job satisfaction for scientists and engineers," IEEE Transactions on Engineering Management, May, pp. 39-42.

Stahl, M. J., Zimmerman, T. W. and Gulati, A. (1984). "Measuring innovation, productivity, job performance of professionals: A design modeling approach," IEEE Transactions on Engineering Management, February, pp. 25-29.

Staples, E. R. (1984). "Impediments to office productivity," Office Administration and Automation, September, p. 85.

Staples, E. R. (1985). "Who's responsible for office automation?" Infosystems, February.

Starr, M. K. (1983). "Building productivity into business school programs," National Productivity Review, Autumn, pp. 410-419.

Starr, S. (1986). "IIE's productivity improvement campaign enters seventh years," Industrial Engineering, January, pp. 91-95.

Stein,H., (1982). Ethics (and other liabilities): Trying to live right in an amoral world, St. Martin's Press, New York.

Steinbrecker, D. (1983). "People probers and super conclusions," Office Administration and Automation, March, pp. 48-56.

Sternberg, D., (1981). How to complete and survive a doctoral dissertation, St. Martin's Press, New York.

Stewart, W. T. and Calloway, R. J. (1982). "Engineering productivity: The management of improvement," Engineering Management International 1, Elsevier Scientific Publishing Co., Amsterdam, The Netherlands, pp. 109-116.

Strebel, P. J. (1984). "The management task in turning a sunset into a sunrise," International Management, September, P. 113.

Suchman, E. A. (1967). Evaluative research: Principles and practice in public service and social action programs, Russell Sage Foundation, New York.

Suhorsky, K. (1982). "High priority required to boost white-collar worker productivity," Communications News, January.

Sumanth, D. J. (1984). Productivity engineering and management, McGraw-Hill, New York.

Sumanth, D. J. (1981a). "Productivity indicators used by major US manufacturing companies: the results of a survey," Industrial Engineering, May, pp. 70-73.

Sumanth, D. J. (1981b). "Survey results: How major non-industrial corporations measure their productivity," Industrial Engineering, September, pp. 32-34.

Sumanth, D. J. (1979). Productivity measurement and evaluation for manufacturing companies, Ph. D. Dissertation, Illinois Institute of Technology (Published by University Microfilms International, #80-03,665), Ann Arbor, Michigan.

Sumanth, D. J., Omachonu, V. K., and Beruvides, M. G. (1990). "A State-of-the-Art Review of Research on White- Collar/Knowledge Worker Productivity," International Journal of Technology Management, vol. 5, no. 3, pp. 337 - 355.

Sutton, H. (1984). "Programs which boost white-collar productivity should consider people environment and automated systems," Marketing News, February 17.

Swain, J. and Sink, D. S. (1984). "Productivity measurement in the service sector: A hotel/motel application of the multi-factor productivity measurement model," International Industrial Engineering Proceedings.

Tanaka, F. J. (1983). "Japan's management illusion," USA Today, March, pp. 20-24.

Taylor, F. W. (1911). The principles of scientific management, (1967 ed.), W. W. Norton & Company, New York.

Taylor, F. W. (1907). "On the art of cutting metals," Transactions of the ASME, vol. 28, pp. 31 - 350.

Taylor, F. W. (1903). "Shop management," Transactions of the ASME, vol. 24, pp. 1337 - 1480.

Templin, N. (1992b). "Four GM Assembly plants are now idle as strike by 2,300 affects added 20,000," Wall Street Journal, September 1, p. A3.

Templin, N. (1992c). "GM and Union reach accord, ending strike." Wall Street Journal, September 8, p. A3.

Thamhain, H. J. (1983). "Managing engineers effectively," IEEE, November, pp. 231-236.

Thor, C. (1987). "Knowledge worker gainsharing," Productivity Management Frontiers - I, February, pp. 305-313.

Threlkeld, J. L. (1970). Thermal environmental engineering, 2nd ed., Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Thurow, L., (1985). "Revitalizing American industry: Managing in a competitive world economy," California Management Review, vol. 27, no. 1, pp. 9 - 41.

Thurow, L. C. (1986). "White-collar overhead," Across the Board, November.

Thurow, L. C. (1980). "The productivity problem," Technology Review, November/December, pp. 40-51.

Trost, C. (1992). "To cut costs and keep the best people, more concerns offer flexibility work plans," Wall Street Journal, February 18, pp. B1, B12.

Turner, W. C., J. H. Mize, and K. E. Case (1978). Introduction to industrial and systems engineering, Prentice-Hall, Englewood Cliffs, New Jersy.

Tutle, T. C. and Romanowski, J. J. (1985). "Assessing performance and productivity in white-collar organizations," National Productivity Review, pp. 211-224.

Ullmann, J. E. (1982). "White-collar productivity and the growth of administrative overhead," National Productivity Review, Summer, pp. 290-300.

Van Maaren, J. (1979). "Reclaiming qualitative methods for organizational research: A preface," Administrative Science Quarterly, vol. 24, no. 4, pp. 520-526.

Van Wylen, G. J. and R. E. Sonntag (1978). Fundamentals of Classical Thermodynamics, 2nd ed., John Wiley & Sons, New York.

Vincent, H. F. and Mirakhor, A. (1972). "Relationship between productivity, satisfaction, ability, age, salary on a military R&D operation," IEEE Transactions on Engineering Management, May, pp. 45-52.

Wallace, W. (1971). Research methods in organizational behavior, Scott Foresman Publishers, Glenview, Illinois.

Weick, K. E. (1983). "Misconceptions about managerial productivity," Business Horizons, July/August, pp. 47-52.

Wilson, J. (1990). Thinking with concepts, Cambridge University Press, Cambridge, England.

Witting, P. H. (1983). "Don't throw that CRT on any old desk!" Data Management, August, pp. 18-19.

Wolfe, C. L. and Vondle, D. P. (1983). "How to solve the information backlog," Management Review, March, pp. 46-50.

Yarbrough, W. V., C. P. Koelling, and M. G. Beruvides (1992). "White-collar work: A classification of clerical endeavors," Working Paper, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Yin, R. K. (1989). Case study research: Design and methods, 2nd edition, Sage Publications, Beverly Hills, California.

Zoch, D. M. and Weiner, R. G. (1984). "Service organizations can use IE techniques to improve productivity of professional workers." Industrial Engineering, August, pp. 45-51.

BIBLIOGRAPHY

Acar, W., (1987). "Theory versus model: Further comments on 'Toward a consistent terminology for management theory building' and rejoinder to Sirgy," Systems Research, vol. 5, no. 2, pp. 172 - 173.

Acar, W., (1987). "The substantive and methodological hierarchies: Rejoinder to Sirgy's response," Systems Research, vol. 5, no. 2, pp. 176 - 177.

Antill, L. (1985). Selection of a research method," in C. Mumford, et. al. (eds.), Research Methods in Information Systems, Elsevier Science Publishers B. V., North Holland, pp. 203 - 215..

ASQC, (1988). Advanced quality planning, American Society for Quality Control, Milwaukee, Wisconsin.

Baker, T. L., (1988). "Varieties of social-scientific research," in Doing Social Research, by T. I. Baker, McGraw-Hill, New York, pp. 15 - 18.

Barker, J. A. (1988). Discovering the Future: The Business of Paradigms, ILI Press, St. Paul, MN.

Barker, P., (1989). "The reflexivity problem in the psychology of science," in The Psychology of Science, B. Gholson et. al. (eds.), Cambridge, pp. 92 - 114.

Barnard, C. I., (1968). The Functions of the Executive, Harvard University Press, Cambridge, Mass.

Bariff, M. L. and E. J. Lusk, (1978). "Designing information systems for organizational control: The use of psychological tests," Information and Management, vol. 1, no. 3, pp. 113 - 121

Behling, O. (1980). "The case for the natural science model for research in organizational behavior and organizational theory," Academy of Management Review, vol. 14, no. 4, pp. 490-495.

Berry, L. L., V. A. Zeithaml, and A. Parasuraman, (1990). "Five imperatives for improving service quality," Sloan Management Review, vol. 31, no. 4, pp. 29 - 38.

Blaylock, B. K. and L. P. Rees (1984). "Cognitive styles and the use of information," Decision Sciences, vol. 15.

Boland, Jr., R. J., (1985). "Phenomenology: A preferred approach to research on information systems," in Research methods in information systems by Richard J. Boland, Jr., Elsevier Science Publishers B. V., pp 192 - 202.

Cheney, P. H. and G. W. Dickson (1982)."Organizational characteristics and information systems: An exploratory investigation," Academy of Management Journal, vol. 25, no. 1, pp. 170 - 184.

Cleveland, J. N., K. R. Murphy, and R. E. Williams (1989). "Multiple uses of performance appraisal: Prevelence and correlates," Journal of Applied Psychology, vol. 74, no. 1, pp. 130-135.

Collins, H. M. (1990). Artificial experts: Social knowledge and intelligent machines, MIT Press, Cambridge, Massachusetts.

Crosby, P., (1990). "Pragmatic philosophy," Productivity SA, April, May, pp. 16 - 19.

Daft, R. L., (1983). "Learning the craft of organizational research," Academy of Management Review, vol. 8, no. 5, pp. 539 - 546.

Daft, R. and R. H. Lengel (1984). "Information richness: A new approach to management behavior and organizational design," Research in Organizational Behavior, vol. 6, pp. 291 - 333.

Deal,T. E. & A. A. Kennedy, (1982) Corporate cultures: The rites and rituals of corporate life, Addison-Wesley Publishing Co., Reading, Mass.

Delbecq, A. L., A. H. Van de Ven, and D. H. Gustafson, (1975). Group techniques for program planning: A guide to Nominal Group and Delphi processes, Green Briar Press, Middleton, Wisconsin.

Deming, W. E. (1990), Quality Productivity and Competitive Position , Notebook for Seminar presented by Dr. Deming, Nov. 13-16, 1990 in Nashville, Tenn. published by Quality Enhancement Seminars, Los Angeles, CA.

Deming, W. E., (1982). "Improvement of quality and productivity through action by management," National Productivity Review, Winter, pp. 12 - 22.

Drucker, P. F., (1990). "The emerging theory of manufacturing," Harvard Business Review, vol. 68, no. 3, pp. 94-102.

Drucker, P. F. (1976). "The coming rediscovery of scientific management," The Conference Board RECORD, June, pp. 23 - 27.

Drucker, P. F., (1967) The Effective Executive, Harper & Row, New York.

Eisenhardt, K. (1991). "Better stories and better constructs: The case for rigor and comparative logic," Academy of Management Review, vol. 16, no. 3, pp. 620-627.

Eisenhardt, K. (1989) "Building theories from case study research," Academy of Management Review, vol. 14, no. 4, pp. 532-550.

Fawcett, S. B., (1991). "Social validity: A note on methodology," Journal of Applied Behavior Analysis, vol. 24, no. 2, pp. 235 - 240.

Finney, J. W., (1991). "On further development of the concept of social validity," Journal of Applied Behavior Analysis, vol. 24, no. 2, pp. 245 - 250.

Follet, M. P. (1927). "Management as a profession," in H. C. Matcalf (ed.) Business management as a profession, A. W. Shaw & Co., Chicago, pp. 73 - 87.

Fossum, J. A. (1992). Labor relations: Development, structure, process, Irwin, Boston, Massachusetts.

Freedman, A. (1988). "How the 1980's have changed industrial relations," Monthly Labor Review, May, pp. 35 - 38.

Galbraith, J., (1973) Designing complex organizations, Addison- Wesley Publishing Company, Reading Massachusetts.

Garvin, D. A. (1984), "What does 'product quality' really mean?" in Quest for Quality, by M. Sepehri, 1987, Georgia: IIE

Geller, E. S. (1991). "Where's the validity in social validity," Journal of Applied Behavior Analysis, vol. 24, no. 2, pp. 179 - 184.

Gold, M. E. (1989). An introduction to labor law, ILR Bulletin 66, ILR press, Ithaca New York.

Goldratt, E.M. & J. Cox, (1986) The goal: A process of ongoing improvement, North River Press, Croton-on-Hudson, N.Y.

Guaspari, J., (1985) I Know it when I see it: A modern fable about quality, Amacon Press, New York.

Hegel, G. W. F., (1987). Reason in history: A general introduction to the philosophy of history, Macmillan Publishing Co., New York.

Heider, J., (1985). The tao of leadership: Leadership strategies for a new age, Adapted from Lao Tsu's "Tao te ching", Bantam, New york.

Henneman III, H. G., D. P. Schwab, J. A. Fossum, and L. D. Dyer (1989). Personnel/human resource management, (4th ed.), Irwin, Boston, Massachusetts.

Hirimoto, T., (1988). "Another hidden edge- Japanese management accounting," Harvard Business Review, July-August, pp.22-26.

Homans, G. C., (1941). "The Western Electric researches," in Fatigue of Workers by George C. Homans, Transaction Publishers, New Brunswick, New Jersey, pp. 56 - 65.

Ishikawa, K. (1971). Guide to Quality Control, Asian Productivity Organization , Tokyo, Japan.

Kanter, R. M. (1983), The change masters, Simon Schuster, Inc., New York.

Kaplan, R. S., (1990). Measures for manufacturing excellence. Harvard Business School Press, Boston, Mass., pp. 15-38.

Kilian, C. S., (1988). The World of W. Edwards Deming, Mercury Press, Rockville, Maryland.

Kilmann, R. H. and I. I. Mitroff, (1976). "Qualitative versus quantitative analysis for management science: Different forms for different psychological types," Interfaces, vol. 6, no. 2, pp. 17 - 27.

Koontz, H. (1961). "The management theory jungle," The Academy of Management Journal, December, pp. 174 - 188.

Kurke, L. B. and H. E. Aldrich (1983). "Mintzberg was right! A replication and extension of the nature of management work," Management Science, vol. 29, no. 8, pp. 975 - 984.

Kurstedt, H. A., (1991). Implementing The Management Process, Working papers, Management Systems Laboratory, Virginia Tech, Blacksburg, VA.

Kurstedt, H. A., P. M. Mendes, and K. S. Lee, (1991). "Engineering analogs in management," Working Paper, Management Systems Laboratory, Virginia Tech, Blacksburg, Virginia, 6p.

Lawler, L. E., (1990). Strategic Pay: Aligning Organizational Strategies and Pay Systems, Josey-Bass Publishers, San Francisco.

Lux, K., (1990). Adam Smith's mistake: How a moral philosopher nvented economics & ended morality, Shambala Press, Boston Massachusetts.

Macintosh, N. B. and R. L. Daft, (1978). "User department technology and information design," Information and Management, vol. 1, no. 3, pp. 123 - 131.

Mann, N. R., (1989). The keys to excellence: The story of the Deming philosophy, Prestwick Books, Los Angeles, CA.

Matejka, J. K. and Ashworth, D. N., (1985). "The employees' hierarchy of greed," Administrative Management, October, pp. 24 -25.

Meister, D., (1991). "The definition and measurement of systems," Human Factors Society Bulletin, vol. 34, no. 2, pp. 3 - 5.

Mintzberg, H. (1990), "The design school: Reconsidering the basic premises of strategic management", Strategic Management Journal, vol. 11, no.3.

Mintzberg, H. (1990), "The manager's job: Folklore and fact," Harvard Business Review, (original printing in July/August edition, 1975), vol. 23, no.3.

Mintzberg, H. (1987), The five basic parts of the organization", in Classics of Organizational Theory, (2nd ed.), J. M. Schafritz and J. S. Ott eds., The Dorsey Press, Chicago.

Mintzberg, H. (1979). "An emerging strategy of 'direct' research," Administrative Review Quarterly, vol. 24, no. 4.

Mintzberg, H., D. Raisinghani, and A. Theoret (1976). "The structure of 'unstructured' decision process," Administrative Science Quarterly, vol. 21, no. 2, pp. 246-275.

Morris, W. T. (1979). Implementation strategies for industrial engineers, Grid Publishing Inc., Columbus, Ohio.

Morris, W. T. (1975). Work and your future: Working harder, living poorer, Reston Publishing Co., Reston, Virginia.

Morris, W. T., (1967). "On the art of modeling," Management Science, vol. 13, no. 12.

Omachonu, V. K. and Beruvides, M. (1989). "White collar/knowledge work productivity monitoring for interdependent functions with no measurable output," Conference Proceedings, IIE International Conference Toronto, Canada.

Peters, T. J. (1988), "Facing up to the need for a management revolution," California Management Review, vol. 30, no. 2.

Peters, T. J. and Waterman, R. H. (1982), In Search of Excellence: Lessons from America's Best-Run Companies. Harper & Row, New York.

Rosenberg, N. (1976). "Karl Marx on the economic role of science," in Perspective on Technology, Cambridge University Press, Cambridge, pp. 126-138.

Rossman, G. B. and B. L. Wilson (1985). "Numbers and Words: Combining quantitative and qualitative methods in a single large-scale evaluation study," Evaluation Review, vol. 9, no. 5.

Ruch, W. A. (1980). "Knowledge worker productivity," Manufacturing Productivity Frontiers, August, pp. 11-14.

Schein, E. H. (1987), "Defining organizational culture", in Classics of Organizational Theory, (2nd ed.), J. M. Schafritz and J. S. Ott eds., The Dorsey Press, Chicago.

Scherkenbach, W. W. (1986). The Deming Route to Quality and Productivity: Road Maps & Roadblocks, CEEPress, Washington, D. C.

Schuler, R. S., S. A. Youngblood, and V. L. Huber (1988). Readings in personnel and human resource management, (3rd ed.), West Publishing Co., New York.

Sink, D. S. (1990). "Developing measurement systems for world class competition," Working Paper, Virginia Productivity Center, Virginia Tech, Blacksburg, VA.

Sink, D. S. (1985). "Strategic planning: A crucial step toward a successful productivity management program," Industrial Engineering, January, pp. 52-60.

Sirgy, M. J., (1987). "Theory versus model: A comment on 'Toward a consistent terminology for management theory building' by William Acar," Systems Research, vol. 5, no. 2, pp. 176 - 177.

Sirgy, M. J., (1987). "Two hierarchical dimensions of research concepts: Rejoinder to Acar's response," Systems Research, vol. 5, no. 2, pp. 176 - 177.

Sirkin, H. and G. Stalk, Jr., (1990). "Fix the process not the problem," Harvard Business Review, July / August, pp. 26 - 33.

Skinner, B. F., (1985). "What is wrong with daily life in the Western World?" Paper presented to the American Psychological Association, August, pp. 15 - 31.

Skinner, B. F., (1982). "Why we are not acting to save the world," Paper presented to American Psychological Association, Aug. pp. 1-4.

Taylor, F. W. (1912). "What is scientific management," Excerpt from the testimony of Fredrick Winslow Taylor at the hearings before the Speccial Committee of the House of Representatives to investigate Taylor and other systems of shop management, January 25, 1912, pp. 1387 - 1389

Thompson, J. D., (1967). Organizations in action: social science bases of administrative theory, McGraw-Hill, New York.

Thurow, L., (1985). "Revitalizing American industry: Managing in a competitive world economy," California Management Review, vol. 27, no. 1, pp. 9 - 41.

Tushman, M. L. and D. A. Nadler (1978). "Information processing as an integrating concept in organizational design," Academy of Management Review, July, pp. 613 - 624.

Vansina, L. S., (1990). "Total quality control: An overall organizational improvement strategy," Productivity SA, June / July, pp. 20 - 26.

Whetter, D. A. (1989). "What constitutes a theoretical contribution?," Academy of Management Review, vol. 14, no. 4, pp. 490-495.

Wittgenstein, L., (1958). The blue and brown books: Preliminary studies for the philosophical investigations, Harper & Row, New York.

Wittgenstein, L. (1953). Philosophical investigations, Macmillan Publishing Co., New York.

Wittgenstein, L. (1922). Tractatus logico-philosophicus, Routledge & Kegan-Paul, London.

Wood-Harper, T. (1985). "Research methods in information systems: Using action research," in C. Mumford, et. al. (eds.), Research Methods in Information Systems, Elsevier Science Publishers B. V., North Holland, pp. 169 - 191.

APPENDIX A: THE RESEARCH PROCESS

This Appendix contains a review and statement by the author on the research process. Research, per se, is not uniform by any stretch of the imagination. Some of the basic beliefs that are representative of the author's view of research are presented. The following topics will be covered. See figure A.1 for a thought diagram of this section's logical development.

A1.0 The Research Process

A1.1 Research Problem and Question

A1.2 The Circular Nature of Research

A1.3 Strong Inference

A2.0 Research Classifications

A2.1 Logic

A2.2 Types of Research

A3.0 Research and Practice

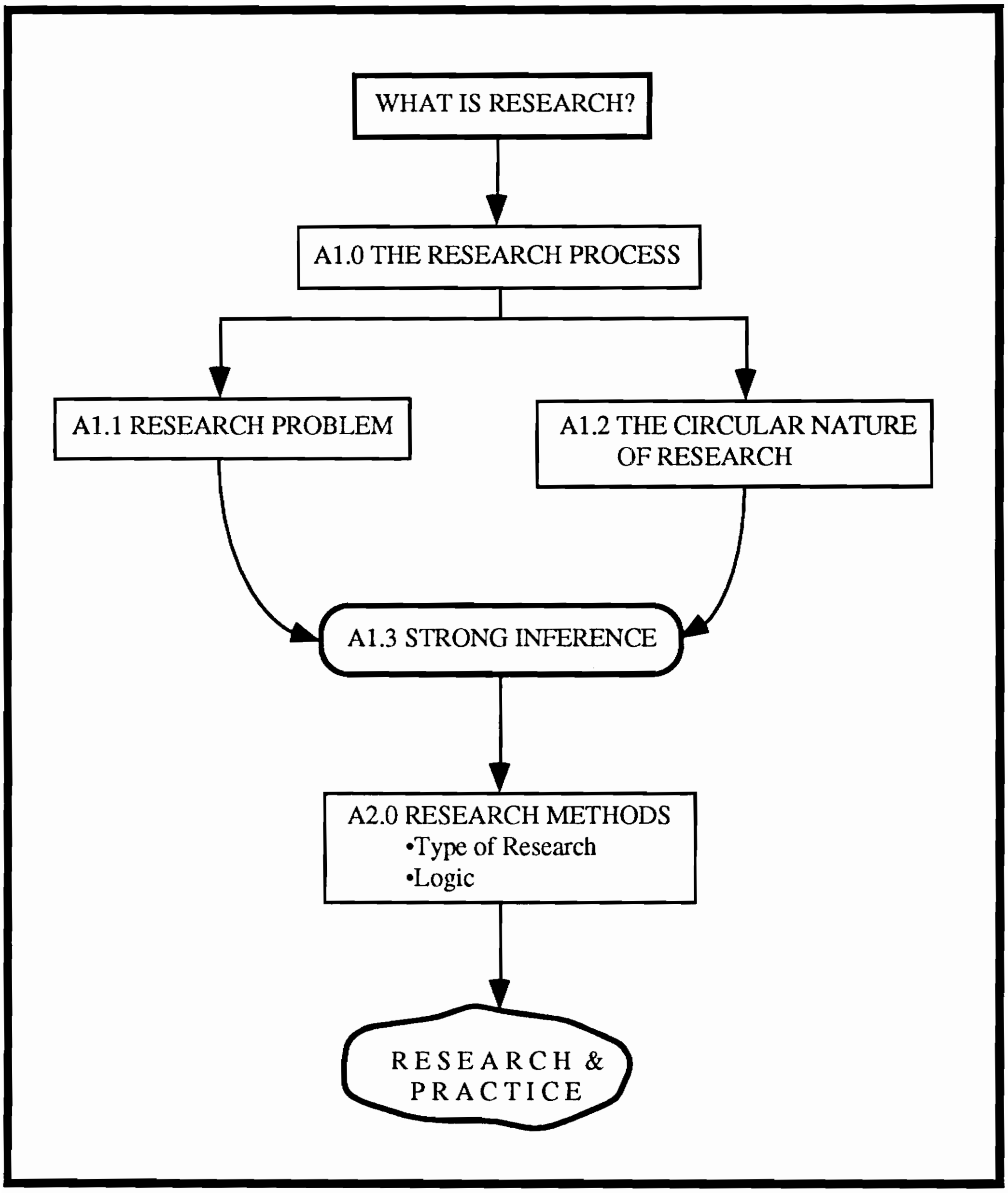

Figure A.1. Thoght Diagram for Appendix A Logical Development.

A1.0 INTRODUCTION TO THE RESEARCH PROCESS

"Research is the procedure by which we attempt to find systematically and with the support of demonstrable fact, the answer to a question or the resolution of a problem" (Leedy, 1989; p. 5). This definition of research by Leedy touches upon a crucial point about research; answering a question or resolving of a problem. Leedy (1989) correctly notes that research is not mere information gathering, transportation of fact from one place to another, rummaging for information, or a catchword used to get attention. The essence of research is the resolution of a basic question that has not been answered at all or to the satisfaction of the researcher.

A1.1 THE RESEARCH PROBLEM AND QUESTION

Kurstedt (1991c) believes that research begins with a question. Leedy (1989) goes as far as to state that "quite simply: no problem, no research" (p. 45).[50] This may seem a bit blunt, but it exemplifies the essence of both theoretical and practical research. But the research problem and question are more than just the seeds of research, they are in fact the driving force in the continuous efforts that are research. This is because most all research efforts of enduring value can be seen as a sequence of in inquiries.[51] This can be seen in Kurstedt's (1991c) three key characteristics of a research question:

---

[50] The research question and problem need not be singular. In fact most scholars in this area believe there are even sub problems and sub questions (Leedy, 1989; Kurstedt, 1991c) just like there are hypothesis and sub-hypothesis.

[51] By this the author does not exclude 'one-shot' research efforts that may have great value to the propagation of knowledge, but stresses the cumulative nature of research is demonstrating a preponderance of evidence to strengthen our knowledge base about a subject area of knowledge.

1. A research question should focus you and stimulate other questions at the same time,

2. have theoretical and/or practical importance,

3. and, generate inferences (p. 12).

Generating inferences begins what is often termed the circular nature of research (Wallace, 1971; Leedy, 1989; Kurstedt, 1991c).

A1.2 THE CIRCULAR NATURE OF RESEARCH

Depicting the circular nature of research was probably best done by Wallace (1971). (See figure A.2 for what is often termed the Wallace Wheel.) Leedy (1989) depicts the circularity or research in a different way (see figure A.3). Leedy sees a progression of six repeating steps (research question, problem statement and conceptual model, sub-problems leading to a research model, hypotheses, data collection, and data interpretation) with a seventh interacting step (support or rejection of hypothesis). The Leedy model is a process descriptive model while the Wallace model is more a model of relationships. In figure A.4, a conceptualization of the Wallace Wheel is provided. This conceptualization is a further exposition of the relationships between questions-answers-and subsequent questions that is at the heart of the circular nature of research. In figure A.4 the interplay between the type, logic, and methodologies of research are evident.[52] We will refer to figure A.4 several times in the remainder of this Appendix.

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52 I believe, as Kurstedt (1991c), that research can be classified by type, logic, and methodology.

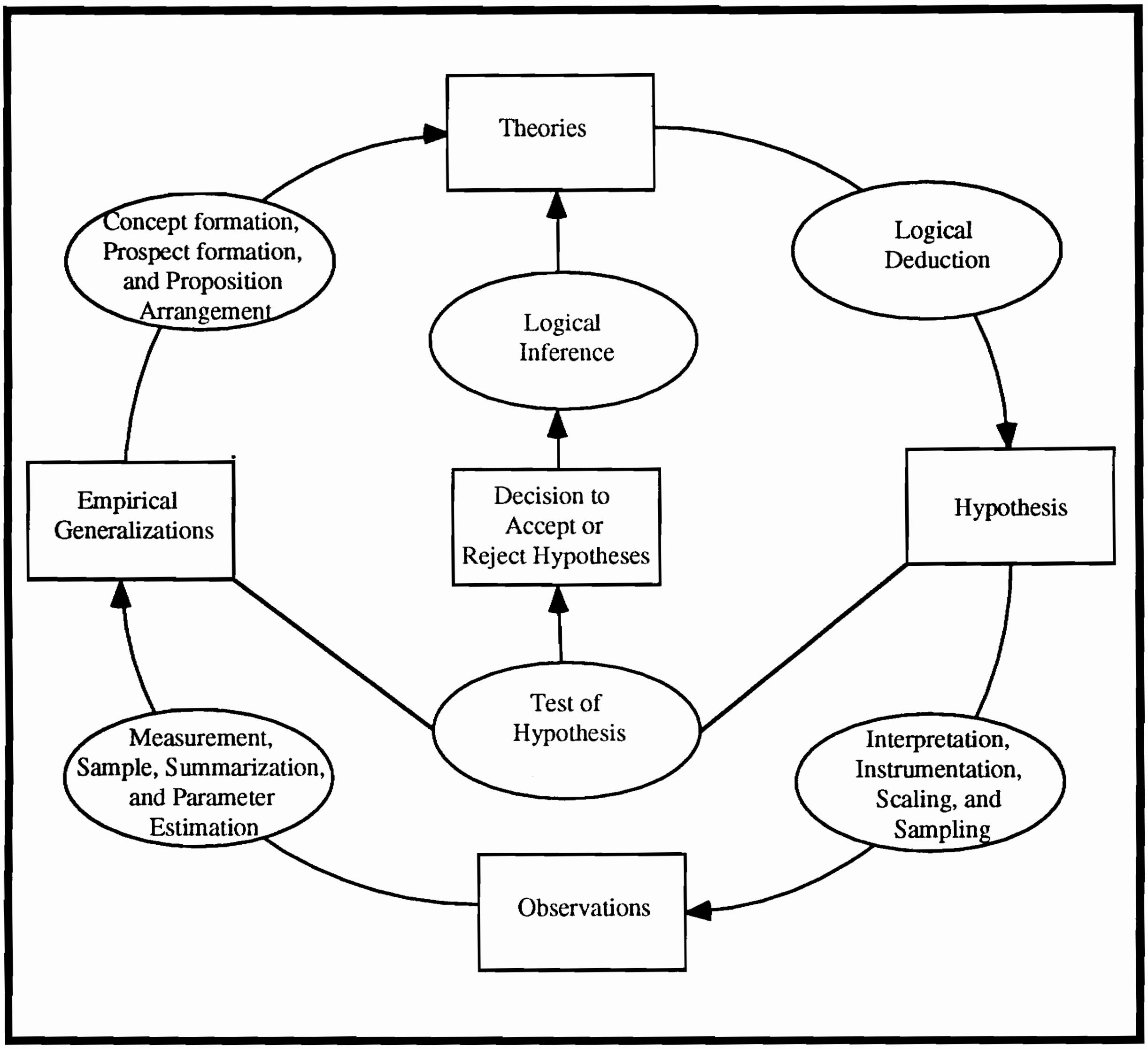

Figure A.2. The Wallace Research Wheel. (From Wallace, 1971).

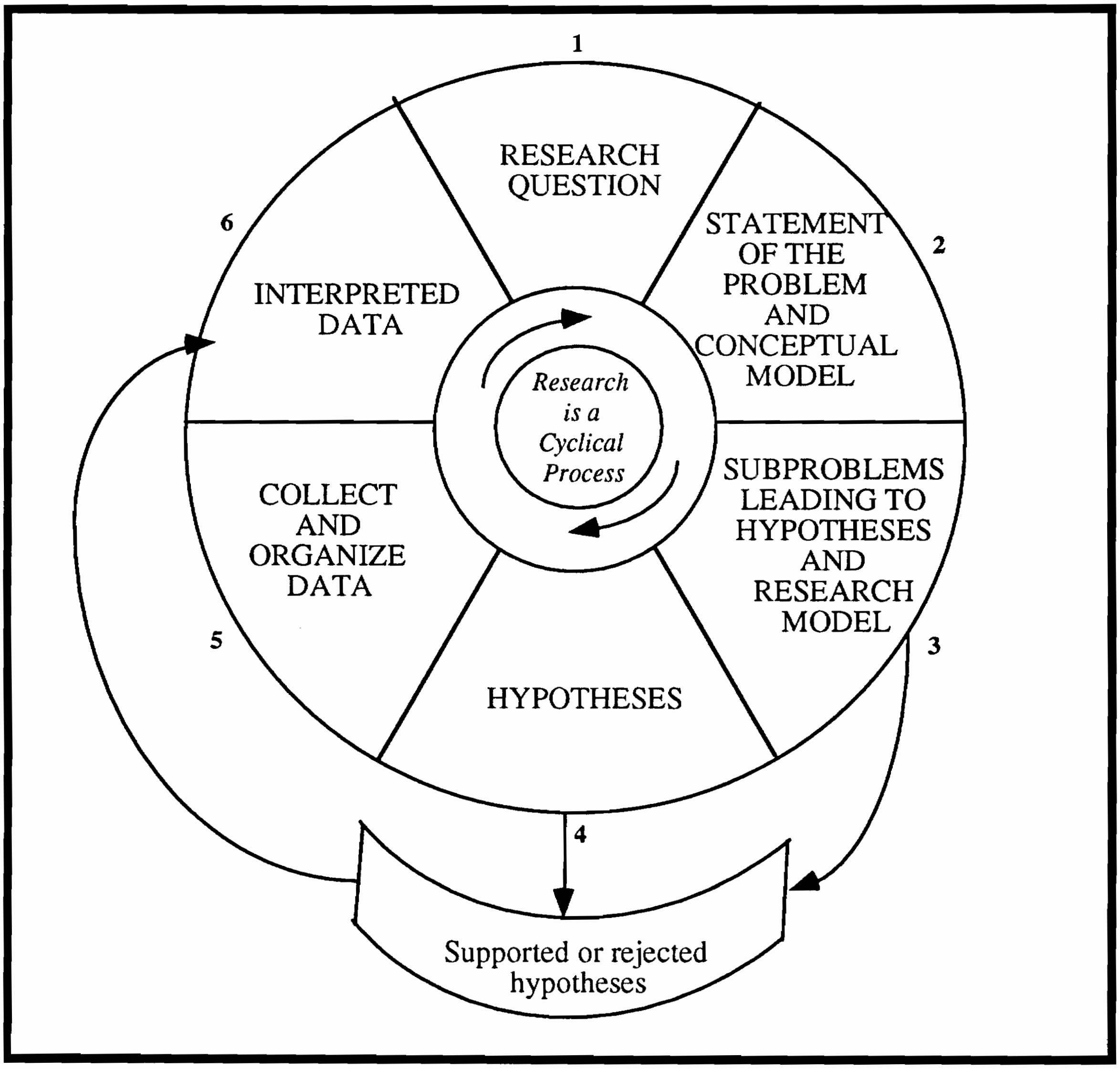

Figure A.3. The research process as represented by Leedy, 1989.

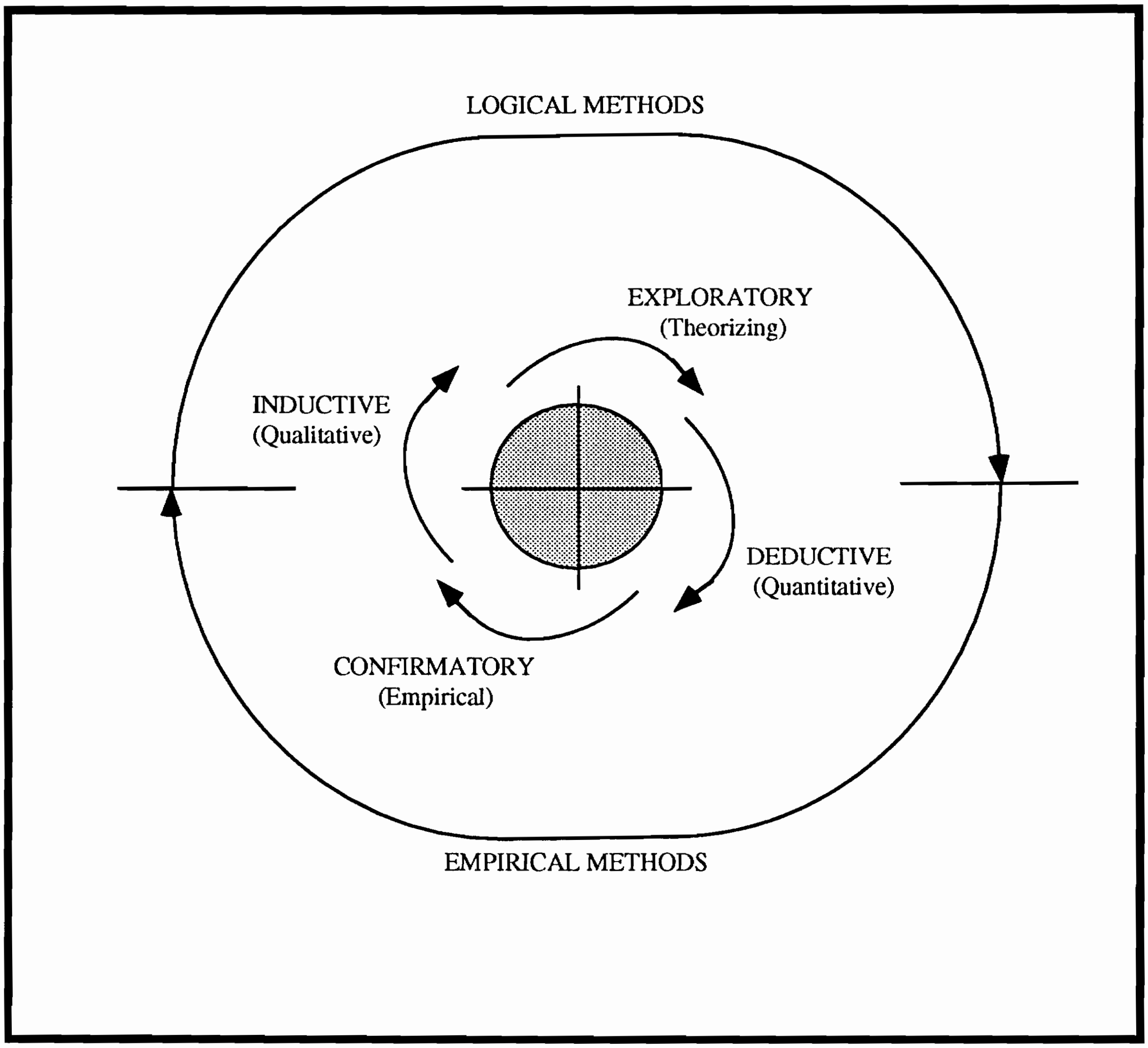

Figure A.4. A Conceptualization of the Research Process.

(Adapted from Wallace, 1971).

A1.3 STRONG INFERENCE

"Why should there be such rapid advances in some fields and not in others? ... I have begun to believe that the primary factor in scientific advance is an intellectual one. These rapidly moving fields are fields where a particular method of doing scientific research is systematically used and taught, an accumulative method of inductive inference that is so effective that I think it should be given the name of 'strong inference'" (Platt, 1964; p. 347). If the circular nature of research does not have an agenda, a goal, then it is quite conceivable that the circularity of research could lead some research effort to 'go around circles.' In fact, research is a spiral (or helix, see Leedy, 1989); a continuous circular process that builds layer upon layer. This spiraling action requires a vector, direction, or agenda.

Platt's (1964) strong inference, by his own admission, is nothing more than the simple old-fashioned method of inductive inference that dates back to Francis Bacon. The difference is that strong inference is based on a systematic application of the inductive inference procedure. Platt lists the steps as follows:

1. Devising alternative hypothesis,
2. devising a crucial experiment (or several of them), with alternative possible outcomes, each of which will, as nearly as possible, exclude one or more of the hypotheses,
3. carrying out the experiment so as to get a clean result, and
4. recycling the procedure, making sub-hypotheses or sequential hypotheses to refine the possibilities that remain, and so on (Platt, 1964; p. 347).

Strong inference is based on constructing rigorous syllogisms.[53] No doubt this is a more natural format for the 'hard sciences.' It may be argued that strong inference is not possible in social science research. Although the rigors of strong inference, as practiced in such fields as microbiology, can not and should not be transported to the social sciences; the general ideas of structure and agenda for research in strong inference are transferable and useful.

A2.0 RESEARCH METHODOLOGIES

Thus, far we have covered several important points in the research process. Research starts with a problem and/or question. The process itself is circular with respect to process and relationships in the types of research conducted. Research should have a direction or agenda (converting the circular nature of research into a spiral) with 'strong inference' as a technique to use in directing such research efforts. This appendix will look at some of the techniques or methods used in classifying research.

A2.1 LOGIC

One way to classify research is by the logic used in the research effort itself; inductive versus deductive (Kurstedt, 1991c). Inductive logic is explaining observation by generalizing; taking a specific situation from facts to general theories. Deductive logic works quite differently; from conjectures (a theory, hypothesis, concept, idea, etc.), data is collected and analyzed to test the validity or strength of the conjecture. Thus, inductive and deductive logic are contrary in the sense that one moves from facts to theory (inductive); the other from theory to facts (deductive), (Light, Singer, and Wilett, 1990).

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53 Webster's Dictionary defines syllogism as a formal statement of argument, consisting of three parts: major premise, minor premise, and conclusion.; the conclusion following naturally from the premises.

A2.2 TYPE OF RESEARCH

There are various other ways to classify research. The type and goal of the research is a means of classification (Kurstedt, 1991c). Research can be termed basic research with the goal to formulate, expand, or evaluate theory. Research can be applied with the goal of seeking solutions to practical problems. Research can be technological which focuses on methodology (Brinberg and McGrath, 1985). The methodologies themselves can be used to classify the research (see table A.1).[54] All these classifications are useful anchors that help us understand and visualize what research is and how to do it. The essential point to remember is that research, like any project, needs to be managed. The methodologies, logic, etc., used are determined by the problem addressed. But the ultimate value of the research is: does it teach us anything new?

Table A.1. Research Methodology Classifications.
(Adapted from Kurstedt, 1991c).

CLASSIFICATION	SOURCES
•Experimental •Theoretical •Empirical	Brinberg & McGrath (1985)
•Survey •Experimental •Fieldwork	Baker (1988)
•Experiments •Field or quasi-experiments •Field studies •Survey research	Kerlinger (1986)

54 This is not all inclusive. There are other ways to classify research by methodology. This is presented as examples of current classifications.

A3.0 RESEARCH AND PRACTICE

The description of *a* research process[55] is a useful venture in helping put together a researcher's beliefs on how to do scientific inquiry. But the practice of research determines the belief in the research itself and further defines the philosophical underpinnings that support a research methodology. Chapter 3 and the research agenda presented in Chapter 2 present my current research structure. The concept of strong inference is a guiding idea at this point in my thinking on research. Through time many of the ideas presented here will develop. I intend to periodically update this small write-up on research. I believe this exercise in making explicit what is many times tacit is a useful tool that strengthens a researcher's ability to conduct scientific inquiries.

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55 By a research process, I am referring to one of many. There are several research processes; each researcher needs to subscribe to one methodology and/or philosophy.

APPENDIX B: PILOT STUDY # 1 DOCUMENTATION

B.1 INTRODUCTION

A small two week pilot study was run April 6 through April 17 of this year (1992). The study was used to test the equipment, logging forms and ideas for the dissertation project being designed. This pilot study in no way was intended to be, nor is presented as a in-depth statistical design to measure work. What is presented in this Appendix is the preliminary effort used to help the researcher better understand the field conditions under which a more rigorous analysis would be run.

In section B.2 (The Preliminary Study), a description of the subject, equipment, forms, and procedures used in the pilot study is described. This is followed by section B.3 (Analysis of the Pilot Study) where the results obtained are tabulated and analyzed. Sub-section B.3.3 presents the 'lessons learned' from the pilot study. These are important in that they directly influenced the design of the dissertation proposal described in this document.

B.2 THE PRELIMINARY STUDY.

B.2.1 SUBJECT

The subject for the pilot study undertaken is a white male (in his late thirties) engineering faculty and assistant department head for a research institution located in the eastern United States. Using only one subject limits the amount of knowledge that can be obtained about the subject matter under study. But the purpose of the pilot study was to analyze the field conditions under which the data for much of the dissertation project would be collected. The single subject was an expedient as well as concentrated effort to simulate the actual data collection scenario.

B.2.2 EQUIPMENT

The subject being analyzed was requested to log data about his work routine at random intervals throughout the work day. To assist the subject, a random time generator device was provided to cue him when to record the data. The device[56] runs on a pseudo random logic (4000 possible combination) with time intervals of 16 to 48 minutes. The device is built with an audio beeper that would serve as the cue for the subject. The device measures 3.5 inches in width, 6 inches in length, and 1.75 inches in depth.[57] The external case was made with thin aluminum sheet metal. The energy is provided by two standard AA batteries with a run time estimated at 50 to 60 hours on a set of batteries.[58] The device contains a toggle switch to turn the machine on and off and a push button to start the random time sequence. A sustained beeping noise is initiated once the device is turned on and will not cease until the push button is engaged. The reason for this is due to the need to supply the random time generation circuitry with different seeds from which to initiate the timing sequence. Once the device is turned on, a fast running counter would be set into motion running a string from 1 to 99. Once the push button is depressed the seed is chosen and the random timing is set into motion.

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56 The random time generating device was designed and built by the Electrical Engineering Lab of the Virginia Polytechnic Institute and State University to the specifications of the researcher. This work was done under the guidance of Dr. Jaime De la Ree of the Electrical Engineering Department Faculty.

57 This size is a bit large and bulky (its prototype design). Further design modifications are planned to make the final project device the size and shape of a normal commercial type beeper.

58 The next design phase will contain rechargeable batteries with battery charger to eliminate the need for battery replacement.

The device was tested for two days by the researcher to validate its functionality before being used by the subject in the pilot study. The subject was then given brief training on the device's functioning.

B.2.3 DATA LOGGING FORM

A data logging form was designed so that information could easily be recorded (see figure B.1). The data requested on the form are date, time, location, purpose of job task being done, function performed, method or technique used to do work task, equipment used, materials, product(s), or services rendered, and any special knowledge required to complete the task.

B.2.4 PILOT STUDY PROCEDURE

The procedure requires the subject to turn on the random timing device each morning at the start of the work day. The subject was required to take the timing device and a notebook with the form along with him through the work day. At each beeping cue the subject would stop and fill out the form. The information to be logged must be for what was being accomplished at this time. This would continue until the end of the work day when the timing device was turned off. The data collection lasted for two weeks or ten working days. The data forms were then collected from the subject.

B.3 ANALYSIS OF THE DATA

B.3.1 RESULTS

The data was tabulated, arranged, and percentages calculated for each of the seven listing on the data form. The results are listed in tables B.1, B.2., B.3, B.4, B.5, B.6, and B.7 respectively. Note the sum count on each table represents each datum recorded for the task listed.

JOB ANALYSIS DIARY LOGGING FORM

DATE: ____________________ **TIME:** ____________________ am / pm

LOCATION: ____

PURPOSE: ____

____

FUNCTION PERFORMED: ____

____

METHOD OR TECHNIQUE USED: ____

____

EQUIPMENT OR AIDS USED: ____

____

MATERIALS , PRODUCTS, SERVICES RENDERED: ____

____

WHAT SPECIAL KNOWLEDGE IF ANY WAS USED: ____

____

Figure B.1. Sample Data Logging Form used in the Pilot Study.

Table B.1. Results of Subject Location Data.

LOCATION	SUM COUNT	PERCENT
1- In Office	94	56
2- Other	64	38
3- In Transit	5	3
4- Personal	5	3
	168	100

Table B.2. Results of Subject Work Task Purpose Data.

PURPOSE	SUM COUNT	PERCENT
1- Meetings with Individuals	37	22.4
2- Advise students	19	11.5
3- Meetings (group/committee, etc)	14	8.5
4- Masters Defense/Thesis Meetings	12	7.3
5- Reviewing (non-res. mat')	11	6.7
6- Personal	10	6.1
7- Telephone calls	9	5.5
8- Fix dept. computers & software	9	5.5
9- Conference	8	4.9
10- Attending class	6	3.6
11- Waiting (idle) or transit	5	3
12- Reviewing (res. mat's-thesis)	5	3
13- Writing	4	2.4
14- Planning	3	1.8
15- Preparation work	3	1.8
16- E-mail response	3	1.8
17- Other (each = 1 time)	7	4.2
		100

Table B.3. Results of Subject Work Function Performed Data.

FUNCTION	SUM COUNT	PERCENT
1- Administrative	81	48.2
2- Faculty	16	9.5
3- Listening/Learning	14	8.3
4- Advising	12	7.1
5- Research	10	6.0
5- Lunch/Personal	10	6.0
6- Work on Computer	8	4.7
7- Planning	3	1.8
7- Walking/Transit	3	1.8
7-Physical Work (unpack Mac/assemble Mac)	3	1.8
8- Reading	2	1.2
8- Typing	2	1.2
8- Writing	2	1.2
8- Chair GSC Meeting	2	1.2

Table B.4. Results of Subject Work Method Data.

METHOD OR TECHNIQUE USED	SUM COUNT	PERCENT
1- One on one discussion / meeting	62	34.8
2- No specified method given	35	19.7
3- Group meeting	20	11.2
4- Reading	12	6.7
5- Writing	10	5.6
6- Review written material	9	5.0
6- Talk on phone	9	5.0
7- Using computer	6	3.4
8- Set-up computer / Load PGM	4	2.3
8- Typing	4	2.3
9- Planning	3	1.7
9-Thinking-	3	1.7
10- Unpack computer	2	1.1
11- Listening	1	0.6
11- Standing	1	0.6
	178*	100

*Note- Sum exceeds 168 because some work methods are listed more than once.

Table B.5. Results of Subject Work Equipment Usage Data.

EQUIPMENT USED	SUM COUNT	PERCENT
1- No equipment used	114	65.5
2- Pen/pencil/paper	22	12.6
3- Computer/Mac/Main frame/Printer	12	6.9
4- Telephone	11	6.3
5- Forms	5	2.9
5- Thesis	5	2.9
6-Manuals	2	1.2
6- Knife	2	1.1
7-White board	1	0.6
	174*	100%

Note- Total exceeds 168 due to dual use listed in some records

Table B.6. Results of Subject Materials, Products, or Services Rendered Data.

MATERIALS, PRODUCTS, OR SERVICES	SUM COUNT	PERCENT
1- No products or services recorded	51	28.3
2- Information	49	27.2
3- Advise (Advising)	30	16.6
4- Letter/memo/agenda/E-mail	18	10
5- Opinion/recommendations	12	6.7
6- Fixed computer/set up computer/fix network	8	4.4
7- Decision	3	1.6
8- To do list	2	1.1
8- Instructions	2	1.1
9-Teaching list	1	0.6
9-Contacts for texts	1	0.6
9- Inventory list	1	0.6
9-C&IE cost summary	1	0.6
9-Unpacked Mac	1	0.6
	180+	100%

Note- Sum exceeds 168 due to more than one product or service listed individual record

Table B.7. Results of Subject Work knowledge Requirements Data.

KNOWLEDGE REQUIREMENTS	SUM COUNT	PERCENT
1- Department policies / equipment etc.	45	17.9
2- None listed	28	11.2
3- Industrial Engineering (in general)	27	10.8
4- Dissertation/thesis/research	19	7.6
5- Computer	18	7.2
6- Faculty: assignments/requests/habits	14	5.6
7- Courses/curriculum (general & specific)	12	4.8
8- Funding/funding mechanisms and activities	11	4.4
8-Human factors	11	4.4
9-Experience	7	2.8
10-Graduate program	6	2.4
11-Statistics	5	2.0
11-Computer software	5	2.0
11-Scheduled events/department activities	5	2.0
11-Advisory board/members/needs, etc.	5	2.0
12-Teaching/syllabus-course content	4	1.6
13- Personal priorities	3	1.2
13-MSL	3	1.2
14-FAIM Conference	2	0.8
14-ASEE Conference	2	0.8
14-ALPHA MI MU	2	0.8
14-Students and needs/UG's/Sr. activities	2	0.8

Table B.7. Results of Subject Work knowledge Requirements Data. (Continued).

KNOWLEDGE REQUIREMENTS	SUM COUNT	PERCENT
14-Research area of work	2	0.8
14- Undergraduate program	2	0.8
15- Publishing	1	0.4
15-IIE activities	1	0.4
15-Secretary work/needs, etc.	1	0.4
15-VPC	1	0.4
15-Phone mail system	1	0.4
15-English grammar/word usage	1	0.4
15-Internship program	1	0.4
15-Applicant qualifications	1	0.4
15-Faculty retreat location	1	0.4
15-Communication basics	1	0.4
15-College/policies, etc.	1	0.4
	251*	100.3**

*Note- Total exceeds 168. Many records list more than one item
**Rounding error

B.3.2 ANALYSIS OF RESULTS

The data from the pilot study presents some rather interesting points for the design of the dissertation research as well as some insight into the type of work done by the subject. The data in table B.1 on location shows that nearly half of the time the subject is not at his regular work site. This has implications on the design of the random timing mechanism used to cue the subject. With the mobility demonstrated here it is possible the subjects in the dissertation research may loose or misplace the timing device. It may be necessary to find some way to secure the device to the subject.

Table B.2 on work purpose shows that the four most frequent responses (accounting for 63.7% of the work responses) are some form of meeting. This is also reflected in table B.4 where the first and third most frequent responses are meetings. The data collection methodology is undoubtedly intrusive. A definite commitment must be obtained from the subjects. The results in tables B.3 and B.5 through B.7 are not seen as giving much data on the field work design implications. Overall, the data show work tasks that are varied requiring an enormous breadth of knowledge which renders mainly intangible outputs. These are very preliminary results, but they do seem to respond closely to the B-W-K work model concept.

B.3.3 LESSONS LEARNED

The lessons learned from the pilot study are as follows:

1. The random timing devices are cumbersome as currently designed. A less intrusive design must be obtained.

2. The mobility of the 'predominantly knowledge work' subjects could lead to the timing devices being lost, misplaced (forgotten). This would result in a loss of data. Some way of securing the device to the subject needs to be devised.

3. The data logging forms are too open ended as currently designed. The subject at times had a hard time distinguishing between purpose and function. The form also does not provide data in a clear and easily manageable format for data analysis, nor does it address directly the B/W/K work model.

4. Training is going to be required to clarify many of the terms used in the form used in the data collection. It is expected that a detailed methodology and training plan must be developed.

5. Although early indications show promise, a specific, quantifiable breakdown of B, W, and K work cannot be obtained with the current design as used in the pilot study.

APPENDIX C: PILOT STUDY # 2 DOCUMENTATION

C1.0 INTRODUCTION

This research focuses on the study of work in general, and the analysis of the field conditions to be used to verify the B/W/K work model (see Beruvides and Koelling, 1992a). This study is a follow-up three day pilot study[59] run December 7 through December 8 of 1992. The study was used to test the equipment and redesigned logging forms for the dissertation research. This pilot study was intended to be a preliminary study to help the researcher better judge the field conditions under which the more rigorous analysis would be conducted.

In section C2.0 a description of the subject, equipment, forms, and procedures used in this second pilot study is described. Section C3.0 contains the results of the study. In section C4.0 the researcher presents the analysis of results and 'lessons learned' from this follow-up pilot study. Finally in section C5.0 a small bibliography is provided as support literature for this preliminary research.

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[59] See Beruvides and Koelling(1992b) for the initial pilot study.

C2.0 DESCRIPTION OF THE STUDY.

C2.1 SUBJECT

The pilot study subject is a male (in his late thirties) engineering faculty member in a research institution located in the eastern United States. The use of one subject limits the study considerably. But the purpose of this pilot study was to further analyze the field conditions under which the data would be collected, not to statistically scrutinize the data results.

C2.2 EQUIPMENT

The subject being analyzed was requested to log data about his work routine at random intervals throughout the work day. To assist the subject, a random time generator device was provided to cue him when to record the data. The random time generation was provided by a Datawriter work measurement instruments model DW02 made by the Royal Dossett Corporation of Excelsior, Minnesota.[60] The device was programmed to a 30 minute seed (average). The device contains several random tables with nineteen numbers, ranging from 0.1 to 1.9 (in 0.1 increments), that are used as multipliers of the seed. Thus, the subject was cued on average two times per hour with the cues in intervals ranging from 3 to 57 minute intervals. The device was tested by the researcher to validate its functionality before being used by the subject in the pilot study. The subject was trained on the proper functioning of the device.

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60 The random time generating device was provided by the Methods Engineering Lab of the Virginia Polytechnic Institute and State University. The researcher wishes to thank Professor Paul Kemmerling for his assistance with this research.

C2.3 DATA LOGGING FORM

A standard data logging form designed for this dissertation research was used (refer to figure C1). The data requested on the form are date, time, location, product / service rendered, equipment used, task knowledge, and a check-off section of the eight work characteristics (outputs, inputs, work type, discretion level, pursuit level, endeavors, decision type, and maturity level) relevant to this research.

C2.4 EXPERIMENTAL PROCEDURE

The procedure required the subject to collect the random timing device and data log notebook each morning at the start of the work day, taking both along with him throughout the work day. Each time the subject was beeped (cued), he stopped and fill out one of the forms. This continued until the end of the work day. The data collection lasted for three days. The data were then collected from the subject.

DATA LOGGING FORM

ID #: ____________ DATE: ____________ TIME: ____________ am / pm

LOCATION: ______________________________

PRODUCT / SERVICE RENDERED: ______________________________

WHAT EQUIPMENT WAS USED? (if any): ______________________________

WHAT KNOWLEDGE IS REQUIRED FOR THIS TASK?: ______________________________

PLEASE CHECK THE APPROPRIATE BLANK FOR THE TASK AT HAND.

1. The **output(s)** produced by this task is/are- ____ Tangible ____ Intangible

2. The **input(s)** required by this task is/are- ____ Tangible ____ Intangible

3. This **type** of work task is- ____ Mainly Physical ____ Requires some Physical ____ Mainly Mental

4. The level of **discretion** I have in this work task is- ____ Little to none ____ Fair ____ High

5. The **pursuit** of this work task is a- ____ Process ____ Project ____ Program ____ Problem ____ Perplexity

6. The **endeavor** of this work task is- ____ Functional ____ Operational ____ Tactical ____ Strategic

7. The **decision(s)** I have to make for this work task is/are- ____ Structured ____ Semi-structured ____ Unstructured

8. The **maturity level** of this work task is- ____ for visibility ____ for control ____ for optimization

Figure C.1. Data logging form for work sampling research.

C3.0 DATA ANALYSIS

C3.1 RESULTS

The data were tabulated for each of the listings on the data form. The results are presented in tables C.1 through C.5. Note that the sum count on each table represents data counts for the task listed.

Table C.1. Results of Subject Location Data.

LOCATION	SUM COUNT	PERCENT
1- In Office	26	65
2- In Class	6	15
3- Other	5	12.5
4- Personal	3	7.5
	40	100

Table C.2. Results of Subject Products, or Services Rendered Data.

PRODUCTS, OR SERVICES	SUM COUNT	PERCENT
1- Advising students	7	15.6
2- Teaching	6	13.3
3- Preparing for class	5	11.1
3- Reading	5	11.1
4- Research	4	8.9
5- Providing information on homework	3	6.7
6- Meetings	2	4.4
6- Preparing class assignment	2	4.4
6- Reviewing papers	2	4.4
7- Reading memo	1	2.2
7- Planning weekly activities	1	2.2
7- Preparing for meeting	1	2.2
7- Checking phone mail	1	2.2
7- Service (serving as subject for a research project)	1	2.2
7- Talking with a colleague	1	2.2
7- Checking e-mail	1	2.2
7- Photocopying	1	2.2
7- Travel	1	2.2
	45	99.7%

Note- Total of 99.7% is due to rounding error.

Table C.3. Results of Subject Work Equipment Usage Data.

EQUIPMENT USED	SUM COUNT	PERCENT
1- None	15	30.6
2- Chalkboard	5	10.2
2- Chalk	5	10.2
3- Files	4	8.2
4- Books	3	6.1
4- Computer	3	6.1
5- Whiteboard	2	4.1
5- Markers	2	4.1
5- Telephone	2	4.1
6- Pencil	1	2.0
6- Paper	1	2.0
6- Daytimer	1	2.0
6- Problem solutions (key)	1	2.0
6- Copy machine	1	2.0
6- Overhead projector	1	2.0
6- Transparencies	1	2.0
6- Briefcase	1	2.0
	49	99.7%

Note- Total of 99.7% is due to rounding error.

Table C.4. Results of Subject Work Knowledge Requirements Data.

KNOWLEDGE REQUIREMENTS	SUM COUNT	PERCENT
1- MRP	5	10.4
1- Materials handling requirements/planning	5	10.4
1- Scheduling/planning	5	10.4
1- Systems engineering graduate program	5	10.4
1- Class plan & materials	5	10.4
2- STORM	4	8.3
3- Manufacturing engineering	3	6.2
3- Simulation	3	6.2
4- Man-machine flow shop	2	4.2
4- Time management /priorities / to do list	2	4.2
5- Heuristics	1	2.1
5- ISE department programs	1	2.1
5- My research	1	2.1
5- Phone mail system	1	2.1
5- Lab development plan	1	2.1
5- Purchase orders	1	2.1
5- Computer operation	1	2.1
5- How to operate copy machine	1	2.1
5- None	1	2.1
	48	100%

Table C.5. Results of Eight Work Caracteristics.

	TANGIBLE	INTANGIBLE
1- OUTPUTS	21	19

	TANGIBLE	INTANGIBLE
2- INPUTS	34	6

	MAINLY PHYSICAL	SOME PHYSICAL	MAINLY MENTAL
3- WORK TYPE	7	8	25

	LITTLE	FAIR	HIGH
4- DISCRETION	6	21	13

	PROCESS	PROJECT	PROGRAM	PROBLEM	PERPLEXITY
5- PURSUITS	16	12	8	3	0

	FUNCTIONAL	OPERATIONAL	TACTICAL	STRATEGIC
6- ENDEAVORS	17	12	7	5

	STRUCTURED	SEMI-STRUCTURED	UNSTRUCTURED
7- DECISION TYPE	20	15	5

	VISIBILITY	CONTROL	OPTIMIZATION
8- MATURITY LEVEL	27	7	6

C4.0 ANALYSIS OF RESULTS

The data present some interesting points with respect to the dissertation research as well as the type of work done by the subject. The data in table C.1 on the subject's location shows that 80% of the time he was in his office or in class. By contrast the first pilot study found a faculty member -with mainly administrative responsibilities- spent nearly half of the time out of his regular work site. This shows a lot less mobility than previously suspected, but this type of work still requires that mobility be considered when designing experimental procedures for job analysis.

Table C.2 shows that the major product or service of this type of work is advising students on an individual basis (15.6%). But if various entries are combined (teaching, preparing for classes, providing information on homework, and preparing class assignments), it is evident that the teaching component of this type of work is the largest of all components (35.5%). Some may argue that advising students might also be viewed as part of the teaching component. Table C.3 (equipment usage) resulted in a finding similar to the first pilot study, with 'none' (no equipment) comprising the largest percentage. The data collection methodology was still found to be intrusive.

Overall, the data reflect similar results to the previous pilot study, where work tasks were found to be varied; requiring an enormous breadth of knowledge(see table C.4). But unlike the first pilot study (which reafirmed the B-W-K work model), the current data relating to the eight work characteristics are inconclusive with respect to the B-W-K work model concept (table C.5). The results (excepting work type and discretion level) do not show any significant trends as expected. Of course, this pilot study contains too little data to draw any valid conclusions, but the results are none the less interesting.

C4.1 LESSONS LEARNED

The lessons learned from this follow-up pilot study are as follows:

1. The cumbersome nature of the random timing device has been somewhat overcome.

2. The mobility of the 'predominantly knowledge work,' although less than expected, is still a concern with respect to losing or misplacing the random time devices. The potential for loss of data is still a risk.

3. Training is still a critical element of this research, since some of the responses to the eight characteristics questions were found to be at odds with the description of the task as described. This may be a result of poor or improper training by the researcher.

4. The data logging form was found to be adequately designed for the task of collecting the information that this research needs.

APPENDIX D: DATAWRITER TECHNICAL SPECIFICATIONS

This Appendix contains the technical specifications, functions, and instructions on how to use the model DW02 Datawriter Work Sampling device. A picture of the Datawriter device is provided in figure D.1, along with specifications, functions, and instructions. Further details on the device are provided in the write-up from the Royal Dossett Corporation which is also included in this Appendix.

Instructions

CHARGE. Plug in charger. Charge for at least 12 hours. The charger may be left plugged in indefinitely.

ERASE. Press the following three keys simultaneously:
- 1 4

SET TIME. Press Fn four times. Set HHMM time, press Etr. 0830=8:30am, 1200=noon, 1530=3:30pm, 0000=midnight, etc.

DATA. Press any of the 15 character keys to display and record the character. Press Bsp to backspace and erase characters.

TIME. Press Tim to display and record time. Press Bsp to erase an entire time entry.

SEND. Connect an RS232C cable. Invoke the receiving program on your computer. Press Fn twice, press Etr.

Fn Functions

Press the Fn key one to six times for various functions. Press Bsp anytime to return to data entry mode.

Ch 15284. Memory left. (Chb or CHP indicates bEEP or PEEP active. Select bEEP or PEEP then press Etr to turn beeper off.)

SEnd9600. Press Etr to send at 9600 baud.

SEnd1200. Press Etr to send at 1200 baud.

HHMM. Enter four-digit 24-hour time, press Etr.

bEEP. Enter four-digit average random-interval in seconds (0010-9990), press Etr (10%-190% intervals).

PEEP. Enter four-digit fixed-interval in seconds (0010-9990), press Etr.

Specifications
Model DW02

DISPLAY: 8-characters
CHARS: 0123456789-FLPᴶ
(Etr = ᴶ)
TIME: ,HHMMSSᴶ
MEMORY: 16000 characters
SEND: 8-bit, no parity
Ctrl-Z eof
SIZE: 1" x 2" x 5.5"
WEIGHT: 6 ounces
CHARGE: 9-18vdc
100ma minimum

WARRANTY: The Datawriter DW02 is warranteed to be free of defects due to materials and workmanship for 90 days from date of shipment.

Cover photo full size

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Tel: 1-612-471-0240
Fax: 1-612-471-8203

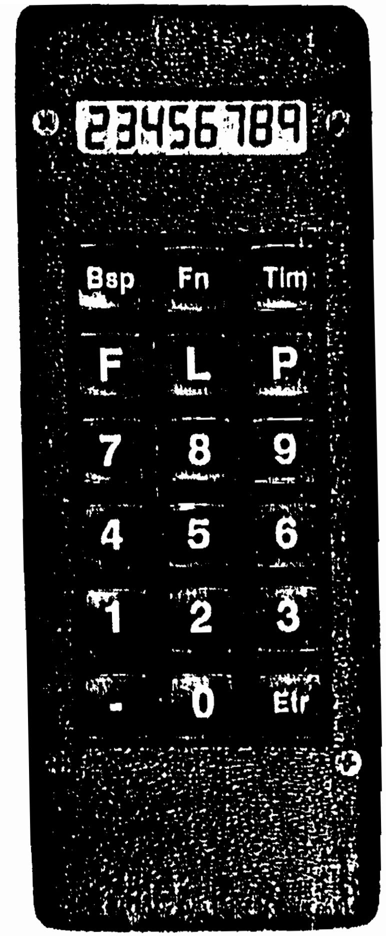


Figure D.1. Datawriter Model DW02.

WORK SAMPLING using the new DATAWRITER and CAS software

The new Datawriter data collector and CAS software offer an unbeatable combination for work sampling studies.

Work sampling (activity sampling) is an incredibly arduous chore if performed manually. Data must be taken on forms, observations counted, and summaries developed using a calculator. It's no wonder that this extremely useful work measurement technique has been often ignored in the past. But that has all changed with the introduction of the new Datawriter data collector and CAS software.

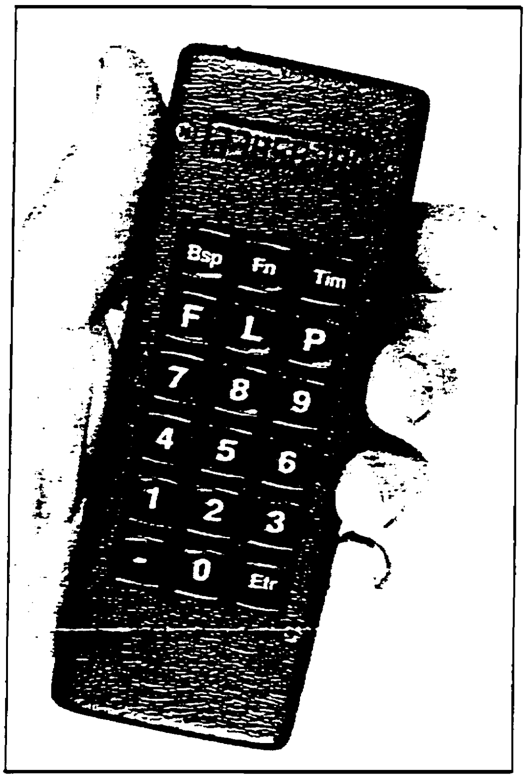
Several data collectors have been marketed for work sampling in the past. The arm-held DataMyte was large, heavy, and expensive, as were other data collectors of the 70's and early 80's. Laptop computers such as the Tandy 102 offer both data collection and limited summarization, but are also heavy, clumsy, and fragile. Hand-held data collectors such as the OS3 and the Psion are smaller, but are very difficult to use and expensive. The new Datawriter is destined to change all that. The new Datawriter is small enough to slip into a shirt pocket, extremely easy to use, and is inexpensive.

The new Datawriter (model DW02) is about the size and weight of a TV remote control, has only a few large keys with tactile feedback, and built-in rechargeable batteries. Battery charge lasts so long the Datawriter doesn't even have an on/off switch. Just pick it up and push buttons.

Taking studies is as simple as entering four-digit codes for subject/element observed. The backspace key (Bsp) backspaces out typos. Observer identification, date, and tour times are also easily entered into the Datawriter.

The data are dumped to your computer and summary reports generated. Study statistics are available in minutes. You can print detailed reports at your leisure; CAS can "zoom" down into the data and develop information-rich summaries.

The picture below shows the Datawriter about 2/3 size. The Datawriter weighs only six ounces, runs several days between charges, and holds over 3000 observations.



CAS. The CAS software offers five main functions, each selected from a main menu by pressing a single key:

DATAWRITER	Datawriter simulator
RECEIVER	Receive data
EDITOR	Edit data
TOURS	Design tours
SUMMARY	Summary reports

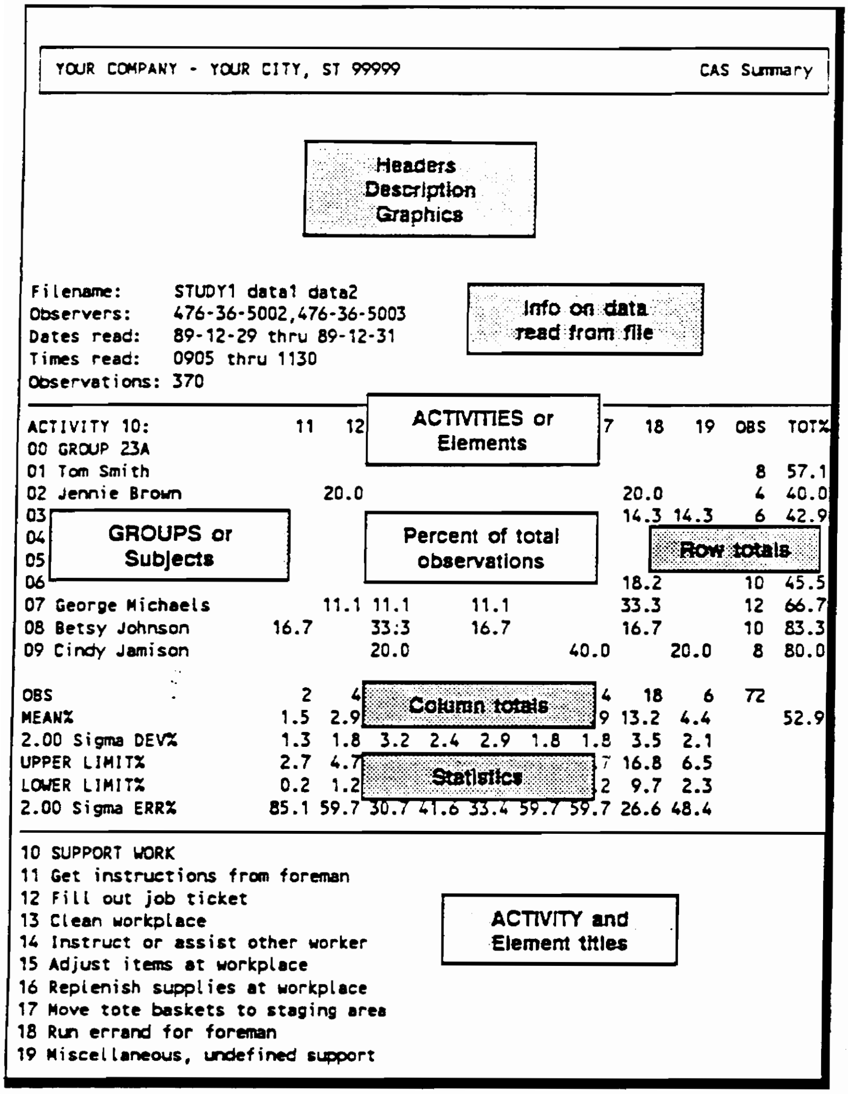
DATAWRITER. This function shows an illustration of the Datawriter on the screen, approximately full size. As you press keys on the computer keyboard, the same key on the screen highlights, and data enters on the display and records in memory exactly like the real Datawriter. All Fn functions (memory status, send 9600 baud, send 1200 baud, erase memory, set clock, set random beeper, set fixed peeper) work exactly the same as on the real Datawriter. Instructions along side the illustration walk you through operation of the Datawriter.

The simulator can be used to introduce users to the Datawriter. (The instructions can be turned off to test for competence.) The simulator can also be used to take and summarize studies on your laptop computer.

RECEIVER. This function receives data from a Datawriter at 9600 baud, displaying received characters on the screen to assure you they were correctly received. The received data can be saved to a new filename or appended to an existing filename. The data are compressed on saving, to make editing of observations easier.

EDITOR. The editor lets you correct any errors in the data such as incorrect codes. The editor also allows you to add header information, study description, and keyboard graphics such as a work-place sketch, and element titles and subject names - for printout on summary reports.

SUMMARY. This function generates summary reports for a date or range of dates (or all), and a range of tour times (or all). Summary displays or prints an overall summary, or summaries for selected groups of subjects, or for a set of sub-activities, or both. A unique "Top10" report summarizes just the ten most-observed sub-activities, in descending order - a very handy report. Summary also can print barchart presentations of an activity. Summary reports can be displayed, printed, and/or sent to a disk file. Summary can produce reports ranging from a simple overall summary on all the data to as detailed as one observer, one day, one tour, one subject, one sub-activity.



DATES. Dates are entered into the Datawriter as YY-MM-DD (example: 90-03-15 is 1990 March 15). The dates are thus in ascending order, making it possible to summarize a date or range of dates - allowing day-to-day comparisons.

TIMES. The Datawriter features a time key which is pressed at the beginning of each tour. Time records in hour-minutes-seconds, forever recording the actual time the tour began. A range of times - say a shift - can be selectively summarized.

RANDOM TOURS. CAS includes a tour schedule generator. Several parameters are presented on the screen. As you change parameters in a "what-if" fashion, the required number of observations, tours, and estimated days displays. When the design is satisfactory, tours can print a complete tour schedule, taking into consideration begin and end time-of-day, and up to three scheduled, non-sampled breaks. Tours can be used to trade "randomness" for days to develop a practical study design.

Alternately, the random beeper built-in to the Datawriter can be used. The beeper is set for average seconds between beeps. For example, set for 600 seconds (10 minutes), the Datawriter will beep randomly but average about six beeps per hour, given enough time. Minimum interval is 10%, or 1 minute; maximum interval is 200%, or 20 minutes.

REPORTS. A sample report is shown on this page - a detailed summary for nine subjects showing a breakdown of the elements in the activity SUPPORT WORK. All CAS reports use the same three-section format - information, summary and statistics, activity titles.

PRODUCTIVITY. The time it takes to work up a summary almost disappears using your computer. CAS and the Datawriter can return your investment on one study. Summaries are error free, and can be far more detailed than ever imagined. And summarization can follow completion of data collection in minutes, not days.

COMPUTER. CAS works on any IBM-PC, XT, AT or compatible with at least 256K memory, and either floppy or hard disk. Color (CGA, EGA, VGA) or laptop LCD is required. The Datawriter holds about 3000 observations (more than a day's observations). CAS can summarize an almost unlimited number of observations.

COST. Now for perhaps the best part. Datawriters are only $295 each, making it possible for you to purchase a Datawriter for each observer in your department. CAT is only $1590, a one-time purchase.

TRY IT OUT. The Datawriter can be purchased on a no-questions-asked return basis. But that may not be necessary. The Datawriter simulator in CAS offers a surprisingly realistic way to "try out" the Datawriter. CAS is available in a student version for only $50 - the full software but limited to studies of 100 or fewer observations. The $50 can be applied towards purchase of the full-capacity CAS program if you like what you see.

APPENDIX E: DISSERTATION MANAGEMENT PLAN

To assure that this research project proceeds in an orderly and well managed manner, the following management plan wss proposed. The plan follows a basic project management scheme.

E1 DISSERTATION GANTT CHART.

The dissertation project plan in Gantt chart format is given in figure E.1.[61] There are four major phases to the project plan: a- proposal stage, b- data collection stage, c- data analysis stage, and d- project report completion stage. The proposal stage was scheduled from May to early October of 1992. Data collection is set to start in mid November 1992 and proceed through early February of 1993. Field work preparation, a substage of data collection, occured in the November through December 1992 time frame. Data analysis commenced in early January and proceed through March of 1993, with the dissertation project report writing set to run concurrently with a start date in mid November through mid April 1993. The dissertation defense was held some time in May of 1993.

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61 The dissertation project Gantt chart given in figure E.1 has a start date of April 1992 commencing with the Pre-proposal document. The dissertation project in fact started before this time. Since the events charted for work prior to this proposal have been completed as planned, listing them would be superfluous. This Gantt chart pertains only to those events dealing with the proposal, data collection, data analysis and report completion phases of this dissertation project.

E.2 MANAGEMENT PLAN.

To manage the research project on an ongoing basis, the Gantt chart milestones were translated into the monthly sub-steps required to complete each Gantt item. This breakdown was reflected in a Scoping Agreement (see section E.2.1) that was contracted between the doctoral candidate and the Ph.D. committee chairman. The monthly items were then further broken down into weekly goals and tasks. These goals and tasks were managed by the doctoral candidate and the Ph.D. committee chairman via a weekly meeting. The weekly meetings (lasting 2 to 3 hours) were characterized by a specific agenda items list that was reviewed by the committee chairman with the doctoral candidate. The meeting also provided a time to present the committee chair with problems, questions, bottlenecks, etc. as well as a time to determine the following week's agenda items.

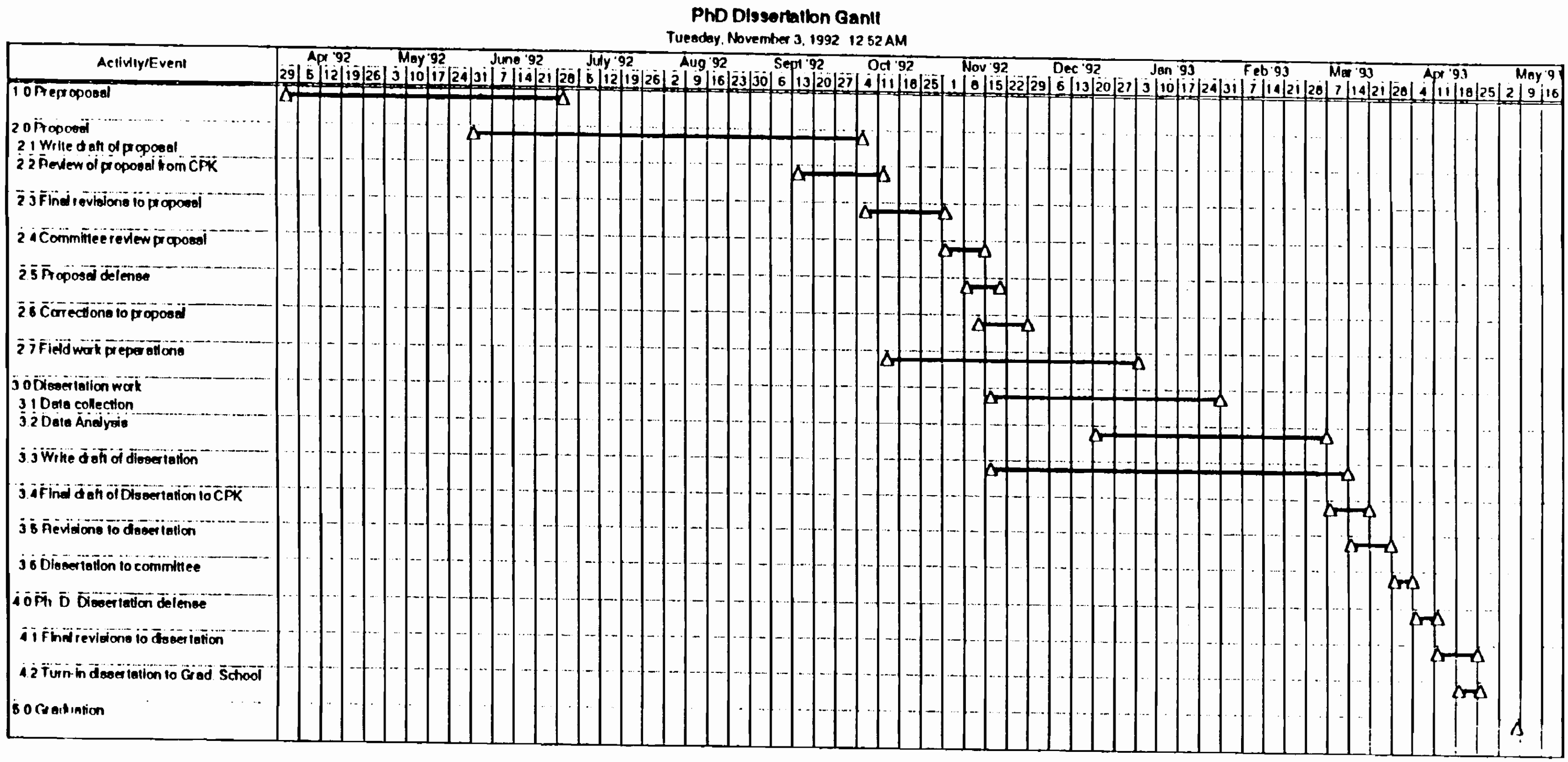

Figure E.1. Dissertation Project Gantt Chart

E.3 SCOPING AGREEMENT

The scoping agreement was a semiformal contract drawn up between the doctoral candidate and the committee chairman detailing the work to be accomplished per semester.[62] The Scoping Agreement was drawn up and turned in to the committee' chairman in the first few weeks of each semester. Upon approval of the work items listed, the parties signed off on the agreement. The scoping agreement contained work tasks for both the doctoral candidate as well as the committee chairman required to keep the project on schedule. The items presented in this Appendix constitute the management plan for this research project.

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62 The Scoping Agreements and management plan have been in use by the Committee chairman and the Ph. D. candidate since the second semester of the candidates Ph. D. program.

APPENDIX F: B GROUP RANDOM TABLES

In this Appendix are listed the three random time tables used by the researcher to cue the B group participants for data collection. Table F.1 lists the random times used for the eleven subjects at the Print Shop. Table F.2 is the table of random times for the 10 participant of ABC Corporation on first shift, and Table F.3, is the table for the 10 participants on second shift. The tables were generated by selecting individual pieces of paper from a paper sack containing all the possible fifteen minute interval time slots[63] written on them. The selection was used with replacement up to three (and at times four) iterations. That is, once a time slot was selected three (or four) times, it was removed from the paper sack. This was done for practical reasons, as the on-site analyst would be overly taxed recording data for more than four subjects in any one fifteen minute interval.

The tables were used by the analyst to cue each subject listed on the specific fifteen minute time interval on the table and thus allow the analyst to fill out the data form. The subjects were each assigned an ID number, the numbers listed on the table. The empty time slots on the tables are intervals when the analyst could not be on-site due to other commitments.

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63 Certain times were excluded from the tables due to a request by the companies involved. Specifically, ABC Corporation preferred that the transition periods between shifts (early in the morning between third and first shift, and mid-afternoon between first and second shift) be excluded to avoid interuptions at this crucial junction of the production cycle. Breaks and lunch were also excluded as this was not relevant to the study.

TABLE F.1. RANDOM TIME TABLE FOR B GROUP DATA COLLECTION
SITE NUMBER 1- THE PRINT SHOP

TIME	3/10	3/11	3/12	3/16	3/17	3/24	3/30
8:00am	18, 19	11,12,18	14,15,21		15,19	14,15,16	12,18,20
8:15	13,20	13,17,20	11,12,20		14,15	11,12,15	16,19,20
8:30	13,15,17	14,16,20	14,15,18		11,16,20	12,17,20	12,16,19
8:45	14,19	11,15,21	14,17,18		16,18	13,14,18	11,13,18
9:00	21	12,18,21	11,19,20	14,20	14,15,18	12,17,20	15,20,21
9:15	11,13,18	16	12,13	16,20	12,13,17	11,13,16,20	20,15,17,21
9:30	11,12,14	14,15,18	15,17,19	11,19	14,20,21	16,18,21	16,18,19,21
9:45	15,17,18	12,19	17,19,21	16,18	14,17	11,15,21	11,16,17
10:15		11,14,16	13,18	18,19	11,13,16	12,15,19	13,19,20
10:30	16	15,21	11,12,20	16,20	11,16,18	12,18,19	13,17,20
10:45	17,20	17,20	12,13	11,14	17,18,21	13,17,20	17,19,21
11:00	16,19	11,13		14,16	12,19,20	11,17,19	11,15,20,19
11:15	14,21	11,13,18		11,20	14,15,17	16,18,21	12,16,17,18
11:30	16,17,20	15,17,19		11,20	11,19,15	15,16,18	12,15,19
11:45	12,15,18	15,19		14,21	11,13,17	11,13,14	13,15,16,18
1:00pm	16,19,21	19		11,16	15,17,19	14,20,21	
1:15	13,20	11,12,16		14,20	14,16,20	14,15,17,21	
1:30	21	12,20,21		18,19,20	11,16,21	11,15,18	
1:45	12,14,16	15,19		11,14,19	15,18,20	12,16,17	
2:00	11,20	14,21		11,12,16	11,18,21	14,21	
2:15	13,15,18	14,19	11,13	14,18	13,20,21	15,19	
2:30	11,19	13,15,17	12,15,20	12,16	15,16,20	13,15,20	
2:45	13,14,15	13,16,20	13,19,20	12,16,20	13,16,17	15,20	
3:15	11,12,17	16	14,15,19	14,20	19,20		11,17,16
3:30	11,18,19	13,18,20	11,12,20	11,16,21	12,15,16		13,15,18,21
3:45	14,21	12,17,15	18,17,21	14,21	14,18,21		11,16,19

TABLE F.1. RANDOM TIME TABLE FOR B GROUP DATA COLLECTION
SITE NUMBER 1- THE PRINT SHOP (CONTINUED).

TIME	3/10	3/11	3/12	3/16	3/17	3/24	3/30
4:00	16,17	16,21	18,15	11,14,21	16,18,19		12,17,20
4:15	12,20	16,17	13,14,21	12,16,20	12,13,17		11,15,17,21
4:30	21	14,18	18,21	16,21	14,19		12,15
4:45	12,15						

TABLE F.2. RANDOM TIME TABLE FOR B GROUP DATA COLLECTION
SITE NUMBER 2 (1st Shift)- ABC CORPORATION

TIME	3/23	3/25	3/26	3/29	3/31
7:00am	35, 38				
7:15	35,38	32,36	31,39	33,34	36,37
7:30	32,36,38	34,40	33,35	31,37	31,39
7:45	31,37	33,39	34	38,37	35,38,40
8:00	36,37	38	36,37,40	31,33	35,38
8:15	33,34,39	32,38	31,33	35,40	31,36
8:30	31,35	32	38	34,36	31,33,39
8:45	35,40	35,37	32,38	31,39	34,37
9:15	32,33	33,40	39	34,37	31,38
9:30	33,38	38,33	31,37	36,34	35,39,40
9:45	34	36,39	36,39	38,31	31,33
10:00	37,39	40,36	31,40	33,35	34,36
10:15	36,39	39,37	34	31,38,40	34
10:30	31,32	33,34,35	33,35,36	37,38,39	37,39
10:45	31,40	33,40	35,38,40	36	35,37
11:00	35,37	38	37,39	34,40	33,34
11:15	33,38	32,38	32,37	35,39	36,40
11:30	39,40	35	32,34,39	33,36	31,38
12:15pm	32,34	34,39	36,40	37	35,38
12:30	36	37,39	31,35	33,31	34,40
12:45	31,36	37,40	33,35,38	34,39	40,35
1:00	33,38	32,34,40	32,40	31,37	36,39
1:15	33,34,40	32,33,36	34,36	35,37	36,39
1:30	35	35,36,38	37	39,40	33
2:00	31,32,39	34,36	32,33,40	35,38,31	33,40
2:15	34,36,40	35,39	34,38	35,40	38
2:30	37				

TABLE F.3. RANDOM TIME TABLE FOR B GROUP DATA COLLECTION
SITE NUMBER 2 (2nd Shift)- ABC CORPORATION

TIME	3/23	3/25	3/26	3/29	3/31
3:00pm					
3:15	41, 43, 49	44,47	44,46	45,48,50	42,47
3:30	47,50	43,45,50	41,45	48	41,47
3:45	42,44,48	43,46,47	41,43	45,49,50	46,49
4:00	41,46	44	45,47,48	43,49	43,45,48
4:15	43,45,49	42,48	44,47,50	41,46,50	42,47,50
4:30	48,50	41,48,49	44,45	46,47	45,49
4:45	47,50	41,42	45,46,49	43,45,48	46,50
5:00	44,46	45,46,49	43,49,50	41,47	45,48,50
5:30	45,47	46,50	41,48	43,48	42,43
5:45	41,49,50	43,44	45,47,45	46,48	47,50
6:00	44,48,50	41,49,50	43,46	47,49	41,47
6:15	43,47	42,47	43,50	41,50	41,46,48
6:30	42,45,49	44,45,46	41,48,50	45,43,41	43,45,48
6:45	42,44,45	47,48	43,47	41,46,50	45,47,49
7:00	46,50	41,43,49	44,48,49	45,50	45,46,43
7:15	41,42,48	48,50	43,45	49,45	41,42,49
7:30	43,46	42,45	46	47,48	

APPENDIX G: W AND K GROUP TRAINING MATERIALS

This Appendix contains the training materials used to prepare the field study participants for proper data collection. Since two different data collection methodologies were used, the materials were applied accordingly. The B group, whose data was collected by an on-site analyst, did not require the self-logging technique used by the W and K group participants. Thus, the B group participants' training consisted of an explanation of the field study, the data form, and questions the analyst would be asking the participant. This training took from 20 to 30 minutes (depending on the number of questions each individual asked) and was done on a one-to-one basis. The W and K group members were required to self-log information about their work tasks when cued by a random beeper. Thus, full training on how to fill out the form was required. The eight work characteristics' definitions were explained to the participants, who were then asked to list five work tasks they usually perform during their work day. A data form was then filled out in detail for each of the listed tasks by the participants with the researcher guiding the individual along and answering any question that arose. This training was also done on a one-to-one basis and took an average of 45 to 60 minutes. With each subsequent data form filled out by the trainee, the researcher let the subject do more on their own. The exercise was repeated until the participant felt comfortable with the form and definitions.

The participants were provided with a telephone number where they could reach the researcher if they were confronted with a situation in which they didn't know how to respond. Several subjects took this option at the beginning stages of data collection until they became proficient with the logging methodology. The training of all subjects ended with the participants having to read an instruction sheet and then sign a consent form to participate in the study. This paper work was part of the Virginia Tech IRB (Institutional Review Board) approval requirements for this study.

DATA LOGGING TRAINING CLASS

This document contains the training information for research currently conducted at the Virginia Polytechnic Institute and State University. If this document is accidentally lost, please return it to the address listed below. Thank you.

Mario G. Beruvides

C. Patrick Koelling, Ph. D.

Department of Industrial and Systems Engineering

Virginia Polytechnic Institute and State University

Blacksburg, Virginia

OUTLINE

1- Review purpose of research.

- Why this study is being conducted.
- What is expected of the subjects.
- Confidentiality and ethics issues.
- Timeline of fieldwork.

2- Instruction on the proper data logging methodology.

- Use of data logging notebook.
- Review descriptors.

3- Sample data logging exercises.

- List 5 common daily tasks.
- Dry run of 5 tasks using the data logging form.

4- Question and answer session.

DATA COLLECTION

DATA LOGGING FORM

ID #: ____________ **DATE:** ____________ **TIME:** ____________ am / pm

LOCATION: ____

PRODUCT / SERVICE RENDERED: ______________________________

WHAT EQUIPMENT WAS USED? (if any): _________________________

WHAT KNOWLEDGE IS REQUIRED FOR THIS TASK?: ________________

____

____

PLEASE CHECK THE APPROPRIATE BLANK FOR THE TASK AT HAND.

1. The **output(s)** produced by this task is/are- ____ Tangible ____ Intangible

2. The **input(s)** required by this task is/are- ____ Tangible ____ Intangible

3. This **type** of work task is- ____ Mainly Physical ____ Requires some Physical ____ Mainly Mental

4. The level of **discretion** I have in this work task is- ____ Little to none ____ Fair ____ High

5. The **pursuit** of this work task is a- ____ Process ____ Project ____ Program ____ Problem ____ Perplexity

6. The **endeavor** of this work task is- ____ Functional ____ Operational ____ Tactical ____ Strategic

7. The **decision(s)** I have to make for this work task is/are- ____ Structured ____ Semi-structured ____ Unstructured

8. The **maturity level** of this work task is- ____ for visibility ____ for control ____ for optimization

DESCRIPTORS

CATEGORY	TERMS
OUTPUTS	Tangible- A physical product or service. Intangible- A qualitative product or service.
INPUTS	Tangible- A physical resource(s) used. Intangible- A qualitative resource(s) used.
WORK TYPE	Physical- Requiring predominantly manual or physical exertion. Semi-Physical- Requiring some manual as well as mental exertion. Mental- Requiring predominantly mental exertion.
DISCRETION	Low- Externally-determined work task assignment. Medium- Partially self-determined work task assignment. High- Self determined (high level of judgment and liberty) in specifying work task assignment.
UNCERTAINTY LEVEL (pursuits)	Perplexity- Can specify neither the start nor the end. Problem- Can specify the start but not the end. Program- Know the start and have qualitative fix on the end. Project- Know the start and have specifications for the end. Process- Repeatedly achieve the same known end.
COMPREHENSIVENESS (Endeavors)	Strategic- Global efforts are aimed in a general direction using qualitative measures. Tactical- Wide efforts are directed toward a tangible result using quantitative standards. Operational- Limited efforts are focused on a fixed outcome using restricted methods. Functional- Local efforts are constrained to an explicit path using specific methods.
DECISION TYPE	Structured- Routine decisions involving information only. Semi-structured- Less routine decisions involving both information and judgment. Unstructured- Unprecedented decisions involving judgment, insight, and intuition with little or no established information.
MATURITY LEVEL	Optimization- Modification of the plan and control to improved performance. Control- Steady state achieved by eliminating variations. Visibility- Complete cognizance of cause and effect relationships.

EXERCISE

List below five (5) common work tasks that you frequently perform through out your work day. Be specific in your description.

1- ____

____

2- ____

____

3- ____

____

4- ____

____

5- ____

____

WORK ANALYSIS STUDY
Instructions for Field Study

Thank you for agreeing to participate in this study. This study is being conducted by the Industrial and Systems Engineering Department at Virginia Tech. The study is being run by Mario Beruvides under the supervision of Dr. Patrick Koelling, a professor in Industrial and Systems Engineering.

The purpose of this study is to investigate the work of several job positions with respect to eight separate characteristics (work outputs, inputs, type of work, level of discretion, pursuits, comprehensiveness, decision type, and maturity level). These eight characteristics have being defined and explained in the training class for subjects provided to you.

The task you will be performing is to log data on your daily work tasks. This involves being cued by either the analyst or the random time generation device provided to you. Once cued you will fill out each of the blanks or questions on the data logging form. You will continue to provide this information each time you are cued for the duration of the field study (2 or 4 weeks/10 or 20 work days). At the end of that time the researcher will pick up the data logging notebooks and random time generation devices you have been utilizing (if you are not part of the analyst recording group).

We are researching the breakdown of your work task with respect to the eight characteristics mentioned above. We are particularly interested in your work tasks composition. After reading these instructions and filling out the informed consent form, you will be ready to start the field study. If for any reason you feel that you can not continue with field the study, please feel free to stop and call the researcher for clarification or to request to be dropped from the study.

The data from the field study should be analyzed by March, 1993. The results will be made available to you should you desire to review them. The research team members are:

Mario Beruvides, Graduate Assistant, ISE; (703) 231-4926

Dr. C. Patrick Koelling, Associate Professor; (703) 231-6656

If you have any questions or concerns about the way you have been treated during this experiment, please contact Dr. E. R. Stout at (703) 231-9359.

Thank you again for your participation. If at any time during the field study you have questions about the experiment, please feel free to call Mario Beruvides. We hope you enjoy your experience in this research effort.

WORK ANALYSIS STUDY
Informed Consent Form

This form constitutes informed consent by you to participate in this study. Please read it carefully, as well as the attached sheet, and then sign it below.

Your rights as a Subject are:

1. It is your right as a subject to withdraw from the study at any time and for any reason.

2. Any of the research team members will answer any questions that you may have and you should not sign this consent until you fully understand all the terms involved.

3. You have a right to see your data and withdraw it from the study if you so desire. Please inform the experimenter immediately of this decision, as the data will be handled anonymously and it is not possible to track your data once the field study is over.

4. You have the right to be informed of any risks or discomforts in this research. There is minimal risk associated with this field study. Since you will be asked to log information about your work tasks as they occur (at random intervals) throughout the work day (for a period of 2 to 4 weeks), no additional risk other than that associated with your normal work routine is expected.

5. Should any further questions arise, please contact one of the team members. If you have any concerns about the way the field study is being conducted or the way you are being treated, you may contact Dr. E. R. Stout's office at 231-9359.

Your participation is greatly appreciated and we hope that you will find the study a pleasant and interesting experience. Your signature below indicates that you have read this document and the description of the experiment attached to it in its entirety, that any questions have been answered, and that you consent to participate in the study described.

Signature: ______________________________ Date: __________

Address: ______________________________

____

APPENDIX H: EXIT INTERVIEW RESULTS

This Appendix provides the results of an informal exit interview conducted with all participants using the self-logging data collection methodology (W and K groups). Eight questions were asked about the data collection methodology:

- describe the methodology (opinion),
- weaknesses,
- strengths,
- what would you change?,
- what would you keep the same?,
- was the data collection methodology effective?,
- suggestions and other comments.

The exact questions and responses are provided in the section that follows. The purpose of these exit interviews was not to provide a strict analytical evaluation of the methodology, but to pole the participants and obtain some insight into how the data collection methodology might be improved for future research.

The results, in general, show a mixture of responses with little consensus on most points. This is exemplified by the responses to question one where the participants were asked to describe (give their opinion) of the methodology. Five respondents found the data collection methodology to be simple, interesting, relatively effective, appropriate, and not a bother. On the other hand, five other participants found the methodology to be very annoying, intrusive, too time consuming, cumbersome, and not well defined. This duality was reflected throughout the responses. For example, almost the same number of respondents believed the data collection form needed to be changed as those who believed it should be kept as designed. It seems that this is reflective of an individual's comfort level with this type of effort. It is possible that not much can be done to overcome the inconveniences of this methodology. But, several points must be noted that are of value. First, the majority of the respondents found the methodology to be effective in gathering the intended data (8 responses), and the remaining three found the methodology to be effective to some extent (pretty good). The randomness and the use of the beeper device seems to be a strong positive. The definitions (terminology) were mentioned by many as hard to understand. This was a point that was believed to be a problem prior to the start of the study. The terminology was not altered because the definitions were those obtained from the literature. It was believed at the time that altering the definitions would, in effect, affect the research itself. This is a point that may be further evaluated now that this initial study used the literature definitions. The suggestions listed under question number seven offer possible alternatives to future research ventures of this nature. Overall, the methodology is viewed as a good design considering the task requirements and the basic intrusiveness inherent in data collection of this nature.

H.1 FOLLOW-UP INTERVIEW RESULTS

1- How would you describe the data collection methodology used in this research?

1- Simple.

- Visibility, optimization and control (maturity level) was the only characteristic I found confusing.

2- Interesting.

- You learn a lot about yourself when you are collecting this data.
- I found it interesting being a subject in a research project.

3- Relatively efficient.

- It was time consuming because of the terminology.

4- A little bit intrusive, but it had to be.

- It didn't bother me from the point of view of what I was doing, but data collection in the classroom was a bit of an interruption.

5- Very annoying.

6- Appropriate for what you are trying to do.

7- Intrusive into my daily activities.

- Found it distractive. It was hard to keep focus and answer the way I should have.
- You didn't get as much into as you could have, I'm impatient.

8- Too time consuming.

- Took away (my personal) productivity.

9- Cumbersome.

10- The categories were not defined well.

- I believe the results will be biased due to subjects lack of understanding of the characteristics.
- Future ratings are influenced by previous answers to same or similar tasks.

2- What were the weaknesses of the methodology?

1- The number of interruptions.

- I didn't understand why beeper needed to be taken to lunch, bathroom , etc.

2- Nothing.

3- Time to complete the form.

- The terminology hard to understand.

4- None.

5- None.

6- I got burned out on it after a while.

- You were not asking me for a lot, but over time it seemed like a lot.

7- Too much effort required to record the information necessary.

- ID#, time, etc. should be automated.

- The time frame was too short. Two weeks is not enough time to judge what I do.

8- Inconvenient.

9- The fact that the equipment needed to be recharged was inconvenient.

- Not sure the beeping schedule gave you a good distribution.

10- Sensitive of the machine to bumps.

11- Difficulty in trying to decide between the different levels of categories.

- Too many categories.

- Took too long.

3- What were the strengths of the methodology?

1- You got a variety of tasks.

2- Information requested (data) was obtained.

3- Having all that data in one page.

- The form was laid out well.

4- Don't know. I'm not capable of judging this.

5- None.

6- Relatively unobtrusive.

- Fairly quick to fill out form.
- Form was asking the right questions. You collected hard data on work.

7- The randomness of the data collection.

- It was very revealing and useful study.

8- It helped me see what I was doing.

9- The sampling of activities throughout the day.

- Doing data collection over multiple days.
- It was a flexible methodology for the subject (carry the forms and equipment with you).

10- It worked well.

- The machine was accurate.

11- It was one way to get all the information you required.

- It collected the information at the time the task was done (work sampling).

4- If you could change any one thing about the data collection methodology, what would it be?

1- Word the eight characteristics differently. The terminology is confusing.

- Maturity level was not descriptive. I didn't understand it.

2- Make the definitions easier

3- Better explanation of terms.

4- A duplicate check off. That is if the same data is to be recorded in consecutive cues, there should be a simple way to indicate a duplicate set of data.

5- Have no idea. Nothing.

6- The amount of time I was asked to collect data.

7- Answering all the questions.

8- A shorter time period would be better.

9- Change the categories. Some characteristics didn't seem to apply to what I was doing.

- Scheduling.

10- Instead of filling out the form, punch in data into beeper.

11- Make the form shorter and simpler.

• One category at a time with a lot more readings (subjects) might be more appropriate.

• There was too much to do.

5- What would you keep (not change)?

1- The discretion characteristic was good.

2- Nothing, it was OK.

3- The beeper was a good idea.

4- Keep the form as is. There is enough information there.

5- Keep it the way it is.

6- The beeper.

- The way in which the whole thing was handled.
  - It was complete, orderly, timely.
  - Well organized.
  - Training session well done. Good logistics.

7- The heading section of the form.

8- The form.

9- The intensiveness and amount of data collected.

10- No response.

11- The beeper (the randomness of the data collection).

6- Do you believe the data collection methodology was effective in collecting the data the researcher was requesting? Why? Why not?

1- Yes, but at times it was repetitious, three minutes is too short of a time cycle.
- Maybe have a longer time span.

2- Yes, it was thorough.

3- It's hard to judge.
- Overall it was pretty good.

4- Yes. Enough data was collected

5- Yes, it was effective.

6- Yes.
- Not sure on how you'll deal with words I put on there.

7- To some extent yes.
- I found myself at times hurried, my responses were not as good as they should have been.

8- Yes, the form was easy to use.

9- Yes, probably.

10- Yes, the results were reflective of what I do.

11- Moderately.
- Got some information, but responses won't be consistent between or within subjects

7- What suggestions would you give to the researcher for future data collection endeavors of this type?

1- Minimum time frame (3 min.) is too short.

- 'Maturity level': eliminate or re-write.

2- Make the definitions easier because the rest is pretty basic.

3- The definitions are the toughest part.

- 'Maturity level' characteristic didn't have any meaning!

4- Have on the form a check off for duplicate of previously done task (repeated tasks).

- Add an attached clock to notebook. I don't wear a watch.

5- I don't know.

- Do it maybe 1 day a week for five weeks.

6- I would like a comment space on the form itself.

- Provide a bit better training. You now have examples from which to build on.
- Have subjects collect data of shorter period of time.

7- Diary would be a better method.

- Look at using video.
- Look at analyst following a person around.
- Do random days.

8- Use a shorter time frame for data collection.

9- Have the person record what they are doing every time they started a new activity, then the subjects should give you how much time the activity took to accomplish the task.

- Change terminology . Use a key or menu at the top of the form to facilitate data collection.
- Have a check off on the form of the equipment used (menu selection). Writing is a bit tedious.

10- The data form and the list of descriptions are not sequenced. They should follow the same order.

- Find a better way of carrying the beeper. I was dressing to be able to carry the beeper.

11- Make form simpler.

- More concrete training.
- Have subjects record what they're doing and have independent person rate it.

8- Do you have any other comments?

1- The study was a little bit annoying, but not bad.

2- No response.

3- No response.

4- No response.

5- No response.

6- No, I found value from this in being part of the research.

7- No response.

8- No response.

9- No response.

10- Beeper sound confusing if two people (in the study) are in the same area.

- The beeper used by federal express people and your machine beeper sounds alike. It can be confusing.
- I did change a number of marks on my responses.

11- No response.

VITA

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Mario Beruvides was born in Havana Cuba on May 25, 1959; the son of Colonel Esteban and Caridad Beruvides. He graduated in December of 1981 with a Bachelor of Science degree in Mechanical Engineering from the University of Miami. Mario worked full time in the plastics and later aerospace materials industry from the time of his graduation until August of 1990 when he entered the Ph.D. program at Virginia Tech. In that time period he attended graduate school on a part time basis, graduating in May of 1988 with a Masters of Science in Industrial Engineering from the University of Miami. His work in industry resulted in design patents registered in the U. S. and Canada. Mario received his Ph.D. in Industrial and Systems Engineering in June of 1993 from the Virginia Polytechnic Institute and State University (Virginia Tech) in Blacksburg, Virginia. His research interests are in work measurement, methods engineering, technology management, quality control engineering, and manufacturing and production systems.

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