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The development of expertise in computer technology: Tracking learning through strategy changes in problem solving

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THE DEVELOPMENT OF EXPERTISE IN COMPUTER TECHNOLOGY: TRACKING LEARNING THROUGH STRATEGY CHANGES IN PROBLEM SOLVING

by

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Table of Contents:

List of Tables: Page

List of Figures: Page

With increasing advances in technology, the normal divisions between "manual" and "intellectual" labor are collapsing; as more industries move toward mediating and controlling work using computerized tools, the kinds of knowledge required of workers is changing. Further, the relationship between technology and knowledge is not at all straightforward; depending upon the characteristics of the systems and how they are used, workers may experience "de-skilling" or may be required to use cognitive skills previously considered irrelevant to their work as it has been historically conceived. For example, with the advent of Decision Support Systems (DSS) -- complex data analysis technologies that assist in decision making but which do not make judgements -- a greater number of workers at all levels must conceptualize work and judge situations on a very different level of abstraction than before. In addition, because of the nature of the processes being controlled, a background in the details of a specific industry is often proving a better prerequisite for effective technology use than, for example, a background in computer systems or computer mediated management. However, many efforts to implement advanced technologies -- such as DSS's -- fail because these systems are difficult for many people to learn, regardless of background. The study described in this dissertation concerns three levels of workers in a large remanufacturing facility learning the logic of MRP (Material Requirements Planning) systems. As will become clear, the important issues may not have to do with identifying who should or can learn these systems, or what is good prerequisite knowledge, but rather how learning occurs among adults who possess prior knowledge and expertise in a related area.

This specific study is embedded in a larger program of research being conducted at CUNY's Laboratory for Cognitive Studies of Activity. The focus of that work concerns the cognitive impact of the introduction of technology into the workplace. Specifically, over the past 10 years, this lab has conducted multiple inquiries exploring how workers' ways of thinking and understanding are affected by changes in the nature of work and workplace organization (e.g., Scribner, 1984; 1985b; 1989; Scribner & Sachs, 1990; Martin & Scribner, 1991). Several lines of research have also been concerned with the cognitive impact of either work or technology change -- either directly or indirectly -- and this work has been influenced by the methods and theoretical models of others whose work falls under various headings, such as "novice-expert shift" (e.g., Chi, Glaser & Farr 1988) "situated cognition" (e.g., Reed & Lave 1979; Rogoff & Lave, 1984; Saxe, 1990), or "naturalistic decision making" (e.g., Orasanu & Connolly, 1993).

However, since the focus of LCSA's inquiry concerns the development of different ways of thinking in different domains, the research has been most influenced by the theories and methods of developmental psychology and particularly the developmental theories of Lev Vygotsky (1978; 1987). Vygotsky's work has become increasingly influential on research in science and technology education (e.g., Davydov, 1988; Hedegaard, 1988; Hedegaard & Chaiklin, 1990; Martin, in press; Moll, 1990) as well as on studies of adult learning (Di Bello & Orlich, 1987; Scribner, 1990; Di Bello, 1992b; Glick, in press; Martin & Scribner, 1991; Scribner, 1984; Scribner, 1985; Scribner, 1985b; Scribner & Sachs, 1990; Scribner, Sachs, DiBello & Kindred, 1991) and, most recently, on those interested in organizational management and the distribution of knowledge in the workforce (e.g., Spender, 1994; in press). The specific aspects of Vygotsky's work that have influenced this study will be discussed in greater depth in what follows. However, at this point it is necessary to indicate that the approach to learning and knowledge represented in his writing is more a framework than an actual "theory", but a powerful framework nonetheless that proved useful to the formulation of questions and analyses that are difficult in more traditional frameworks applied to questions of adult learning.

The study described in this dissertation stems from early efforts at this lab to examine the relationship between school-based kinds of learning and "experiential" learning. Traditionally, knowledge systems that have developed over several generations and are largely transmitted to learners in the form of text or other symbolic forms (two examples are mathematics and physics) have been taught using a classroom based method of instruction while experiential knowledge (that which can be acquired by individual experience) has been traditionally learned through discovery, through on the job learning or through apprenticeship training. With the increasing use of computer based systems of information flow and control in the work place different demands are being placed on the relationship between experiential learning and classroom kinds of learning. The kinds of things adults are required to learn "on the job" in the course of working resemble more and more the kinds of theoretical, formalized knowledge normally presented in a classroom and explored as an object for study, rather than as a means to do real things.

Some of the early research at LCSA focussed on identifying the factors associated with learning MRP and using it effectively in the workplace. MRP was selected as a domain because it represents a class of technology that is widely known to require users who understand its underlying principles (in the sense described by Dreyfus & Dreyfus, 1986 or Polanyi, 1986) and it has a high failure rate because it is so difficult to learn. It was especially difficult for those who already had considerable manufacturing experience. These studies are applicable not only to MRP but perhaps also to the broader issue of learning complex technologies.

A description of one study will illustrate the intention and results of this early research and lay some groundwork for introducing the current study. In a series of case studies of workers using MRP (Scribner, Di Bello, Kindred & Zazanis 1992) in two different factories -- one with a successful implementation and one with an unsuccessful implementation -- classroom instruction seemed to be uncorrelated with effective use of MRP (Scribner et al 1991; Scribner et al, 1992). Yet some individuals manage to master these systems. The study's goal was to define mastery in this domain as well as identify the factors that led to mastery. Not surprisingly, good "book knowledge" of MRP and performing well on written tests were not associated with using the system well. In contrast, workers considered to be effective users had an integrated understanding of the relationship between the system and actual manufacturing processes. That is, they understood not only MRP's in-depth properties, but also had good knowledge of manufacturing practices and were able to coordinate these two often contradictory systems. On-the-job activity proved to be critical to developing the necessary skills, and yet it was certain kinds of activity -- not activity in general -- that made the difference. An analysis of day to day job activity by people in three comparable "titles" and levels of responsibility revealed two distinct patterns of activity. The difference between these two activities is best characterized as "constructive" versus "procedural". Briefly, constructive activities are those that have clearly defined goals and poorly defined means. The employee is compelled to develop a procedure, form, tool or artifact which accomplishes the goal in an iterative fashion, obtaining feedback from more knowledgeable superiors only after attempting to develop a workable solution on her or his own. In contrast, procedural activities are those that have clearly specified means and order of execution, but goals which are either clearly conveyed, or not conveyed at all. Constructive activities are associated with an in depth understanding of MRP's underlying logic (and its relationship to actual manufacturing practice), and procedural activities are not, even if the employees perform essentially the same functions and even execute the same kinds of actions most of the time. In fact, when several variables -- job title, years of experience, level of formal education and number of opportunities (weekly) for constructive activities -- were correlated with measures of in depth grasp of MRP principles, only number of opportunities for constructive engagement was found to be significantly associated with mastery ($r = .69$ $p = <.01$) (see Di Bello and Glick, 1993 for discussion). However, this study also showed that opportunities for constructive activities (and hence, in depth learning) are usually fortuitous and ill structured. For example, they often occur because the person who does know what to do has left the job without documenting procedures for others to use.

Exploring the impact of Constructive and Procedural Activities:

In the study conducted for this dissertation, the relationship between "constructive" and "procedural" activities is further explored in an ongoing study of skilled manufacturing workers (individuals with expertise in the skilled trades) who are learning MRP at the New York City Transit Authority's re-manufacturing facility which is chiefly responsible for maintaining and re-manufacturing subway trains. This study differs in a number of significant ways from the previous MRP work and from other research on employees using complex computer systems. First, these workers were introduced to MRP in a two day workshop that engaged the workers in intensive constructive activities before they encountered MRP on the job. In the previous MRP studies it was not possible to observe learning as it occurred because the MRP systems had been in place at the time the studies were conducted. This railroad facility had no previous history of using MRP, had a largely traditional manufacturing operation and wished to implement MRP to deal with gross overspending on materials and a history of "reactive" planning and purchasing. The facility allowed us to develop the training that workers would receive just prior to implementation. Secondly, the workshop was designed so that it would engage workers with constructive and procedural activities in a more controlled way than is possible in "real life", using a hands-on simulation or "game" that permitted participants to invent procedures for running a factory with MRP logic, but with little actual risk. This format allowed for the exploration of the relationship between "constructive" and "procedural" activities and learning.

What is MRP?

MRP stands for a family of computer-based systems that integrates information from all aspects of a company's operations and uses it to make decisions (recommendations) regulating production and inventory.

MRP has been characterized as a theory of manufacturing. It instantiates certain key economic concepts such as zero inventory and just-in-time production and is based on principles of manufacturing (for example, formulas regulating how future orders are forecast) developed over the last several decades (Harrington, 1974; Hendrick & Moore, 1985; Timms & Pohlen, 1970). Its objects and procedures are generically defined and the system is content-free until implemented in a particular plant. Its power as a predictor is contingent upon the type and quality of the data used (the content upon which the logic operates) and the extent to which its assumptions match the way things are actually made in a given setting.

Employees working with the system must translate the company's anticipated demand into a form that the MRP system can understand. This is done via a Master Production Schedule (MPS) which the system then interprets as a set of long range, abstract production goals for the company's finished goods. Many times this is actually a "forecast" of how many finished goods will be required to meet demand, but often it represents what the company wishes to sell. The considerations that determine what is actually represented in the Master Schedule depend upon the industry or business.

With the information the system has on "what" a particular finished good is (e.g., what parts go into it, what operations are involved, how long it takes to make each of its component parts and assemble it finally) it makes recommendations for every action leading up to the company's pre-set goals. This includes deciding upon start-dates and quantities for production orders and determining the most efficient pattern of purchasing. Essentially, MRP calculates "dependent" demand, i.e., those components, parts, materials and processes required by the end items. In contrast, "independent demand" means only the demand for the finished goods (e.g., customers' orders, the company's "wish list" for sales, expected demand from other outside sources, etc.), which is represented in the Master schedule, but calculated or determined by human beings and never the system.

MRP is often relegated to the role of inventory database when (for whatever reason) employees cannot make use of its higher functions. In this case, its implementation is not considered successful by industry standards. As indicated in our previous work, "success" in industry terms is highly dependent upon how well workers understand the system and its way of representing the products of their plant (Scribner et al., 1991).

There are three non-obvious principles that organize the logic of MRP and mastery of MRP seems clearly related to grasping these organizing ideas. This is not surprising in that numerous studies in the "expertise" literature point to the importance of underlying concepts (e.g., Chi, Glaser & Rees, 1982).

A full exposition of these principles comprises a bit of a digression from the main point of this dissertation -- learning among adults -- but in order to make sense of the results, it is necessary here to describe them. First, MRP conceives of all parts, assemblies and finished goods as <u>hierarchically arranged items</u>, residing on "levels" that roughly map onto how a given item is manufactured. For example, the system requires such a representation of parts and finished goods in order to calculate "dependent demand", an important function of MRP systems for most industries (although not in, for example, "process" oriented industries such as bakeries). The system uses the item hierarchies to determine what is "dependent" on what. Secondly, rather than using a present to future representation of time, the timing of events is calculated beginning with a future date and moving back to the present. This is referred to as phased time. Thirdly, quantities are not absolute, but time and item relative. When making inquiries about how many of a given part are in inventory, the system calculates a virtual or relative quantity, based on a number of time sensitive factors. Although these principles seem quite simple on the surface, they organize the data and operations of MRP in ways that strike most people as counterintuitive because they are very much at odds with traditional manufacturing ways of thinking and doing. In a sense, it is MRP's counter intuitive structure that makes it so difficult to use.

A primary assumption in the study described herein -- as well as all the MRP work conducted at LCSA -- is that grasping the basic underlying principles of any system is critical to the kinds of knowing implicated in individual mastery. Grasping the core underlying principals differentiates the "expert" from one who is competent at performing pre-learned procedures. The basic difference is that the "expert" can -- using her knowledge of the system's structure -- generate new procedures or solutions to problems not encountered before. In other literatures, this kind of knowledge has been referred to as "flexible mastery" (e.g., Polanyi, 1986) and the concept has been most recently and thoroughly handled within the cognitive science literature on expertise (see review in Chi & Glaser, 1988).

Given the heavy reliance on a concept of mastery borrowed from the cognitive science literature on expertise in juxtaposition with a theoretical orientation heavily influenced by Vygotsky, it is necessary at this point to review these literatures as they bear on the issue of knowledge acquisition. The following section will make clear how these various literatures have influenced the study of knowledge acquisition and cognitive development among adults and will clarify some of the issues addressed in this dissertation.

The history of the study of expertise:

In recent years, there has been a growing interest in studying the development of expertise or the acquisition of specialized knowledge among adults. This trend began within a cognitive science tradition, starting with attempts to build artificial intelligence systems and expert systems in the 1960's and 70's. Results from this research challenged the notion of general cognitive capacities and drew attention to domain-specific knowledge as it resides in individuals.

> In AI research, it became widely acknowledged that the creation of intelligent programs did not simply require the identification of domain-independent heuristics to guide search through a problem space; rather, that the search processes must engage a highly organized structure of specific knowledge for problem solving in complex knowledge domains. (Glaser & Chi, 1988).

The ensuing work on domain specific knowledge contributed reliable descriptions of experts' and novices' ways of thinking in specific domains. For example, various models of problem solving in physics and chess were formulated using detailed studies of experts and computer modelling (deGroot, 1966; Chase & Simon, 1973; Chi, Glaser & Rees, 1982). However, investigators looking at the acquisition of knowledge in domains as diverse as game rules and x-ray diagnosis found that expertise showed common characteristics, regardless of domain, presenting the seeming paradox of a universal phenomenon that manifested itself only in a domain specific way. Much of the work on expertise shows the tension generated by this contradiction, as researchers struggled to identify both the general characteristics of an "expert" (which may or may not generalize to thinking and problem solving in other domains) and the specific hallmarks of expertise within a domain. In a sense, these enterprises go hand in hand; since mastery exhibits itself at a level of subtlety and detail unobservable by ordinary methods, close analysis of problem solving in specific was needed to identify level of mastery in general.

Not surprisingly, this work required investigators who themselves had some knowledge of the target domain and a good philosophical understanding of the underlying concepts organizing such domains. Recently, the general characteristics of experts from diverse domains were summarized by Glaser and Chi (1988) in a volume dedicated to discussions of these early descriptive efforts (Chi, Glaser & Farr, 1988). The list below is adapted from this summary. According to Glaser and Chi, experts are characterized by seven features:

1. experts excel mainly in their own domains;
2. experts perceive large meaningful patterns in their domains;
3. experts quickly solve problems with little error;
4. experts have superior short term and long term memory when performing in their domains;
5. experts represent a problem in their domain at a deeper (more principled) level than novices; novices tend to represent a problem at a superficial level;
6. experts typically try to "understand" a problem before attempting a solution, as opposed to novices, who plunge immediately into applying known equations or recipes for solving the problem;
7. experts have strong self monitoring skills; that is, they know why they fail to comprehend and when they need more information.

<u>Other theories of expertise; differences and similarities between them</u>

A review of more recent literature shows that the seminal concepts of "novice" and "expert" ---- as defined in cognitive science -- and the notion of a "novice to expert shift" have spread to several lines of investigation in psychology, such as educational psychology and industrial psychology. In addition, mastery has been studied in a great many areas of knowledge, such as: medicine, music, art criticism, fire ground control, juggling, computer programming, litigation, law enforcement and corporate management.

The explanations of expertise are nearly as numerous as the studies, however. Closer inspection of these differences reveals three theoretical roots. First, influenced by a heuristic that employs computer models as metaphors for human thinking, many researchers have invoked "change in processing" explanations (Chase and Simon, 1973; Posner, 1988; Charness, 1988; Gentner 1988; Ericsson and Polson 1988; Staszewski, 1988; Groen & Patel 1988; Lesgold, Rubinson, Feltovich, Glaser, Klopfer & Wang 1988; Koedinger & Anderson 1990; Tanaka & Taylor, 1991). That is, experts perform better than novices due to a more efficient mental model which manages memory storage, memory retrieval and the execution of routines more quickly. Others, influenced by the classical theories of emergent, stagelike development have invoked theories of domain specific development that proceeds along Piagetian lines (Piaget, 1963) with an emphasis on ontological reorganization (e.g., Feldman, 1980; 1986; Campbell 1990, Campbell & DiBello 1994). Lastly, there are those who look for domain general capacities that seem related to expertise in a specific area, and propose that these capacities are already well developed in experts or become well developed in order to permit expertise (e.g., Coleman & Shore 1991). Each of these positions contributes in a different way to an increasing understanding of expertise, but speak such radically different languages that integration of perspectives is rare and cross-talk among researchers prohibitively difficult.

Despite the diversity of the domains studied and the myriad psychological models applied to explain expertise, a number of consistent themes re-emerge in the descriptions of the differences between novices and experts, many of which were identified in the early work and summarized in Glaser and Chi's list. These all concern the identifying psychological characteristics of novices and experts and can be summarized as follows:

Novices:

- have memorized routines, recipes or procedures which they retrieve and execute in a linear fashion;
- cannot trouble-shoot efficiently; e.g., they are more likely to "try everything" rather than identify a narrow range of more likely possibilities;
- cannot extemporize in novel situations for which they have no experience or example formulas;
- may perform well on tests of explicit knowledge, such as verbal or written tests, but perform more poorly in the actual application of knowledge, or on performance based exercises in which the correct procedure is not pre-identified;
- classify problems and solutions according to their surface similarities and differences;
- are somewhat "un-selfconscious"; they are unaware of their level of mastery and cannot distinguish their erroneous behavior from

correct problem solving.

Experts, on the other hand:

- often have a difficult time articulating what they know; their knowledge seems to reside at the level of intuition.
- Can improvise a solution to a variety of novel problems, showing considerable flexibility in the handling of their knowledge.
- classify problem types and categories of information differently, i.e., according to deep structural concepts as opposed to surface similarities.
- have gone through clearly identifiable stages of development which have structural similarities that hold true across domains.
- may exhibit special general capacities (such as superior spatial reasoning) but these capacities seem confined to the domain of expertise or those close to it. For example, superior spatial performance or memory in an architect may be exhibited only for architectural problems and may not transfer to other domains, such as geometry.

Clearly, the characterization of experts as differing qualitatively from novices, in the way they think and approach problems (as opposed to quantitative differences in how much is known) has withstood the test of time, even if the explanations for this difference show little convergence. However, this work has also served a more important purpose than mere description; the various conceptions of expertise have consequences for some fundamental issues in psychology, leading the study of expertise to exceed its original boundaries. In particular, a number of our assumptions about human development and ways of knowing have been implicitly challenged.

Implications for developmental psychology

For developmental psychology the work on expertise has called into question the whole notion of "general and emergent cognitive development" as described by the Piagetian tradition and prompted many educational psychologists to rethink their notions of general ability. For example, Keating (1990) has proposed reformulating the problem of intelligence and intelligence testing in terms of charting the development of domain-specific expertise and calls for the replacement of general mental abilities with cognitive activities. Addressing the traditional view that general ability precedes specialized skill, he indicates that domain general capabilities and domain specific expertise may instead develop in parallel and influence one another. Several studies support his notion of complementary development (e.g. Miller & Stigler 1991; Amsel, Langer, Lautzenhiser 1991; Novick & Holyoak 1991) while others do not. For example, some studies showed that specialized training led to specialized cognitive abilities -- such as superior memory for musical forms (e.g., Hatta & Mitsuda 1991) -- but these special cognitive abilities did not transfer to other domains.

Such challenges are compatible with another set proposed by the "culture and cognition" perspective, and the work classified loosely under the rubric of "situated cognition". This work (e.g., Frederickson, 1988; Shweder 1990; D'Andrade, 1990; Lave 1988, 1990; Scribner, 1987, 1990; Stigler & Perry 1990) led to a greater appreciation of the ways in which culture and the social arrangement of things influence the development of cognitive skill, both generally, and in specific domains, sometimes causing two domains normally thought of as the same to reside apart in the same person, an example being "school math" and "shop-keeper math" (Beach 1990; Carraher, Carraher & Schliemann, 1985).

Scribner's research on cognition in the workplace

Particularly relevant here, is the early work of Sylvia Scribner, who discovered specific cognitive consequences to different kinds of activities in different cultures and later developed a more inclusive model of the cognitive consequences of cultural forms, symbolic systems, and tools of all kinds (Scribner 1974, 1975; Scribner & Cole 1974; Scribner & Cole 1981).

Toward the end of her career, Scribner developed an interest in the notion of "flexible expertise" (Scribner, 1987) and began to explore the workplace as a powerful arena for the development of domain specific cognitive skills and ways of thinking about objects. Scribner's approach will be presented in detail as it is an inherently developmental approach to knowledge acquisition and has greatly influenced the theoretical foundation for the study conducted for this dissertation.

This work addresses the notion of the "what for" of knowledge, or the way that "leading activity" or the knower's conscious goals exert an impact on the course of knowledge acquisition and the subsequent operating cognitive model. Specifically, Scribner believed that an individual's conception of the purpose for the activity and the desired outcome exerted an influence on the way that activity was organized. In turn, organized activity influenced the development of an individual's understanding of the related domain.

Scribner independently developed a number of ideas consistent with Activity Theorists (Wertch, Hagstrom, & Kikas, in press) and eventually refined a number of conceptual distinctions within Activity Theory in formulating her broader program. This approach allowed her to frame the issue of knowledge acquisition as a general issue of great importance in psychology that could be reliably studied at the level of detail afforded by in depth investigation of individuals acquiring specific kinds of knowledge. Specifically, she sought to approach knowledge acquisition in a way that took into account: (1) the developmental character of knowledge acquisition; (2) the fact that it is often acquired "for a purpose", or in the context of doing a job or participating effectively in a context mediated by tools and symbols; and (3) the impact of domains themselves. As some of the work in expertise has shown, "masters" in many domains share common attributes, such as flexibility, but not all attributes of mastery are seen in all domains (e.g., Voss & Post 1988). Scribner wished to explore the possibility that there may be certain broad classes of domains that afford different kinds of mastery and more importantly, different cognitive and developmental implications. In her later work, she analytically distinguished between "formal" and "empirical" organizations of knowledge to assist in sorting out the relationship between "kind of expertise" and "kind of development", proposing that a given domain and its overall organization may have specific implications for the kind of developmental mechanisms involved (e.g. Scribner & Sachs, 1990; Scribner, Sachs, Di Bello & Kindred, 1991).

After her death, work by her associates continued to refine the notion of activity and its role in cognitive development; this work (Scribner, Di Bello, Kindred & Zazanis 1991; Di Bello, Kindred & Zazanis 1992; Di Bello 1992; Kindred 1992; Zazanis 1992; Di Bello & Glick 1992) has already been described on pages 4-6. As indicated, these studies aimed to identity the factors associated with in depth understanding of MRP systems as exhibited in the workplace and led to the distinction between two broad classes of activity that may have differential cognitive impact, at least with regard to in depth learning or "flexible" expertise in essentially "formal" domains of knowledge.

Although the discovery of the relationship between kind of activity and kind of knowledge acquired is compelling, these studies and findings were made in settings where this new technology had been in place for 3-5 years. Therefore, the exact relationship between class of activity and the development of in depth learning could not be specified.

However, this work poses an interesting set of questions. Other developmental work indicates strong evidence for epigenetic stagelike development in all kinds of domains, suggesting that any kind of activity would "push" development along a predictable path. The distinction between "constructive" and "procedural" engagement suggests that certain kinds of activity may have a profoundly different effect, reorganizing and developing knowledge according to different principles.

Summary of research and further questions and problems

One way to summarize the collective contributions of the research discussed above is that we now have a working descriptive model with which to approach the general issue of acquisition of expert knowledge and a number of concepts and methods for identifying relative levels of mastery. In addition, we have a greater understanding of the powerful cognitive consequences of the individual's activity, the learning environment and tools embodying the collective knowledge that is to be transmitted.

However, we still have very little insight into the actual process of development itself in different kinds of domains and in different acquisitional settings. For example, although the notion of "reorganization" of knowledge is at least tacitly accepted by many researchers, the mechanisms and rules governing such a process are little understood. Prior knowledge and assumptions about the domain are observed to either facilitate or impede development of new knowledge, but little is known of how new knowledge is built upon old, is impeded by old, or how new experiences or knowledge eventually leads to the deconstruction of old ways of thinking. In addition, little is known about "how" a goal or context organizes knowledge, or how two domains are coordinated, when, for example, an individual who is expert in one field incorporates a new technology that is related, but which is organized according to very different theoretical assumptions. In this sense, the current state of this eclectic work has left us with more developmental questions than answers. Three issues particularly beg further exploration:

1. The development of mastery in a given domain seems to involve mainly cognitive reorganization of existing conceptual structures. While the "addition" of new knowledge occurs, it may occur in accord with an appropriate conceptual understanding of the domain, and not vice versa. Some work suggests the "reorganization" takes place as the refinement and elaboration of naturally occurring intuitive concepts (diSessa 1983; Carey, 1985; Clement 1985). In other work -- such as that dealing with knowledgeable learners who are "crossing" domains (e.g., linear programmers learning object oriented

programming) -- the reorganization may involve the deconstruction and gradual reorganization of existing abstract conceptual systems. (See Campbell, Brown & DiBello, 1992; Campbell 1990 for instances of "domain crossing".) Either way, the process of knowledge acquisition toward mastery appears to be essentially developmental, i.e., qualitative, orderly, and, broadly speaking, stagelike.

2. Discussions of mastery almost always talk about or imply knowledge in terms of the underlying principles, or core organizing concepts of a given domain -- i.e., those conceptual assumptions that, if absent or changed, would alter the domain completely and which organize the relationships between subconcepts.

3. The development of specific concepts appears to be influenced by the kinds of activity taking place when learning occurs; as indicated above, "constructive" and "procedural" activities have been shown to correlate with in depth and "shallow" learning respectively. However, the relationship may be even more specific than suggested in previous work. That is, development within a domain can be uneven if constructive engagement does not compel engagement with all core concepts equally. In addition, "constructive" activities pose a challenge. If they do exert a specific effect, how or why does this happen? Why is something like extensive practice not a substitute?

The study of expertise could be greatly enhanced by a unified research program that incorporates these issues. However, the studies of expertise also collectively present a number of practical, methodological obstacles. In the following section, these methodological issues are discussed in detail. A research framework incorporating some of the fundamental assumptions of Activity Theory is proposed as a way to overcome some of the methodological problems and study expertise in a content-rich and ultimately more unified manner. However, this effort should not be conceived as an attempt to elaborate or clarify Activity Theory. Rather, it should be viewed as an effort to contribute to the basic enterprise of examining the development of domain specific knowledge, using theoretical and methodological tools that allow this issue to be addressed for what it is, the appropriation of culturally constructed systems of meaning and practice by individuals.

Methodological Issues for Developmental Studies of Expertise

Framing the problem:

From the work discussed so far, we can see that the acquisition of knowledge in a specific domain is a complex interplay of many factors. The problem has been to design studies which can incorporate multiple considerations in interesting ways.

A major obstacle to studying the development of mastery in any given domain is a lack of methods for tracking the course of transformation at various points. When the inquiry is focused on the development or reorganization of conceptual thinking, the methodological lack is shown on three levels.

First, instruments that track "larger" changes are simply not sensitive to shifts in conceptual thinking, and more specifically, to reorganizations that lead to the specialized kind of flexible mastery that is the hallmark of expertise. It has long been recognized that specialized measurements of mastery need to be developed for each domain, and usually with the help of recognized experts in the field. A general method for identifying the developmentally important elements of a domain -- those that act as "markers" of cognitive change -- poses an even more vexing problem, one that even experts in the given domains may not be able to help with. That is, relative experts are known for possessing their knowledge in such an "intuitive" and implicit manner, that elaborate methods have to be developed to elicit their ways of thinking and render them into some kind of explicit form (e.g., see Gordon, 1992; Ford & Adams-Webber 1992;

Prerau et al 1992; McGraw, 1992; Hoffman & Klein, 1992). Those studies that manage to provide descriptions of conceptual differences between novices and experts usually confine themselves to "well charted" domains, such as physics or chess, where several generations of domain refinement and even philosophical enterprise have yielded useful descriptions of core concepts and hallmarks of mastery. With "newer" but no less complex domains, such descriptions do not exist. We need a valid method of identifying such core conceptual assumptions in order to study mastery in a broader range of domains.

Secondly a broad framework for defining and discussing different kinds of domains is needed to tackle the more complex problems of knowledge acquisition. For example, we need to differentiate the defining features of a given domain or kinds of knowledge. If we were interested in the mastery of only one specific domain by "pure" novices, then perhaps the distinction between domains would be of no concern. However, when we are addressing the more complicated questions involving learners already "expert" in one way of thinking at a particular level of abstraction in a given domain -- pointing to the question of how empirically acquired knowledge influences the acquisition of a formal system of representing the same domain -- we must pay attention to the larger characteristics of knowledge systems.

A third methodological obstacle is presented when collected data requires analysis. Does each domain require its own set of analytic methods for sorting out and making sense of the behavior of subjects at various points in their development? Even if we could identify what to observe or measure, what manner of analysis can reasonably assure us that we are not just reproducing and reinforcing our own notions of expertise in that domain? A more general method is required in addition to those displays of obvious competence, before we can really be sure that some "deep" change has occurred.

Very few existing approaches can take into consideration the complex interplay of these factors. However, the work of Scribner and her associates shows that framing the problem within an Activity Theory perspective offers certain advantages. The recent work of the Laboratory for Cognitive Studies of Activity (Scribner, Di Bello, Kindred & Zazanis 1991; Di Bello, Kindred & Zazanis 1992; Di Bello 1992; DiBello 1992b; Kindred 1992; Zazanis 1992; Di Bello & Glick 1992; Scribner, Beach & Zazanis, 1992; Glick, in press) has addressed a number of these methodological issues, although they have not yet been applied to studying the actual process of development. Following a brief review of Activity Theory -- and some of the methodological advances made at LCSA -- is a discussion of how this framework can be applied to the problem of development in progress.

Activity Theory

The framework that has been particularly successful for framing the study of learning in context has been Activity Theory, as first presented by Leontiev

(1978), based in part on the work of L.S Vygotsky (1978; 1987), and later elaborated by Davydov (1984; 1988), Gal'perin (1969), and Zinchenko (1985). There are several major ideas explicit in Activity Theory that permit its useful application to adult learning. However, many of these ideas are also relatively under-developed. As discussed in the previous section, in the course of bringing a relatively theoretical and abstract system to bear on actual research in the fieldsite, Scribner and her associates found it necessary to extend this framework in such a way that it was useful for guiding research.

A major idea of activity theory is that knowledge acquisition is part and parcel of activity systems, whether or not they were intentionally designed as learning activities. The individual is seen as participating in an ongoing developmental process by virtue of acting in the world, using tools and accomplishing goals. That is, as an individual acts upon objects and tools, she does so according to her understanding of what is to be done and how to do it. As she carries out her activity, experiencing the results of her actions and things (and information) encountered while doing, all serve to further change her understanding of the same thing. Her subsequent actions in the same domain reflect this and so the cycle continues.

This characterization of knowledge acquisition provides a framework for considering the way that activity influences cognitive development and for recognizing the learner's agency in the learning process. However, activity theory provides only a loose "method" for identifying "activity" in a concrete setting and the features of activity which influence development in one direction or another are still not well understood. In addition, the role of tools and artifacts is unclear. Are these devices used only as extensions of the self to "act upon" other objects, or do they also "act upon", producing developmental effects of their own? If activity has a significant developmental impact, this is an important question. Clearly artifacts and tools embody information and invite or constrain activities of different kinds (e.g., Norman 1990). The last implication of this characterization is that a clear notion of activity is necessary to studies of its cognitive consequences.

It would seem that certain aspects of activity have critical cognitive consequences while others do not, and that different levels of an activity may exert differential force. In addition, it may be that the structure of activity itself (what is left undefined and what is clearly defined) may have impact. For example, according to Leontiev (1978) and Wertsch (1985) activities have three embedded levels. These are operations, actions and goals. The conscious goal is the purpose for the entire activity. The actions are the steps to accomplishing the goal, and the operations are the actual procedures and things done as part of the actions. For example, when writing a letter, the goal is correspondence, the action is writing a letter according to a particular form (on paper, with a pen or typewriter, using a stamp for mailing) and the operations are the actual acts of typing, stamp licking and so on. Although this is a clear and theoretically important conceptualization, it proved difficult to apply in actual empirical research. For example, for two individuals performing the same behaviors, the goals for one may be actions for the other.

Activity Theory and Its Characterization of Knowledge Systems

Activity theory assumes that knowledge systems are created through social practices among particular social groups. That is, knowledge systems are not only inner mental structures, but a body of ideas, facts and practices existing among social groups or communities. As certain anthropologists (Borofsky, 1991; Geertz, 1973), and philosophers of science (Lektorsky, 1988; Longino, 1990; Popper, 1972) have maintained, conceptual systems are social products and have a social reality.

However, the precise manner in which the "social" nature of knowledge is theoretically represented is yet to be fully developed. As developed by Leontiev, the acquisition of knowledge within activities is treated under the Marxist concept of "reflection." The general idea is that humans act in ways that are physically and socially constrained by objective social and physical arrangements. Since knowledge derives from the structure of activity, knowledge can be seen not as a thing in itself - but rather as the reflection of the physical and social constraints that guided the activity that produced the knowledge.

However, this conception of the matter leads to some difficulty when it is applied to the problems of adult learning and for studies of expertise. If knowledge were simply a "reflection" of the forms of socially organized and constrained practical activities we would expect knowledge to merely be a formalization of empirical practices. Yet coming to know a particular system of knowledge involves the development of knowledge that goes beyond knowing how to function within the system. The flexibility that characterizes "expertise" must come from this deeper knowledge of properties and principles and an ability to apply them to unique situations.

These considerations point to the manner in which Leontiev's development of activity theory differed considerably from Vygotsky's theory. Vygotsky, in his discussion of the difference between tools and signs (Vygotsky, 1978, Chapter 4) and between "scientific" and "spontaneous" concepts (Vygotsky 1987; Chapter 6) distinguished between knowledge that was based upon the "reflection" of practical activity and knowledge that was based upon relationships between concepts (for discussion, see Di Bello & Orlich, 1987 and Davydov, 1988). Activity theory, as developed by Leontiev, is well suited to deal with the knowledge that is based on reflection, but not well suited to deal with knowledge that is based on relationships between conceptual elements.

For this reason, this dissertation is based on a Vygotskian notion of knowledge, and particularly his distinction between "scientific" and "empirical" knowledge (Vygotsky, 1978; 1987). However, this distinction is reframed somewhat as a distinction between "formal" and "empirical" in the sense described in Di Bello & Orlich (1987). The use of this distinction is explained in the sections that follow.

The Application of Activity Theory to Adult Development

During the course of the MRP studies described so far, Scribner and her associates were attempting to apply activity theory principles to empirical research on adult knowledge acquisition. In fact, this was generally true of the work by Scribner and her associates since the mid 1980's. However, the latest of this work -- the MRP studies -- embodies the clearest examples of direct attempts to use the general accepted tenets of activity theory to explore adult cognitive development. Scribner undertook this enterprise with the MRP studies in part because of the nature of MRP systems; MRP was conceived by Scribner as a formal theory of manufacturing (Scribner et al 1991) and she was interested in examining the broader issue of how workers coordinated their empirical knowledge of manufacturing production practices with a formal system of knowledge such as MRP. Below several of her general methodological advances are discussed as they emerged in her MRP studies.

Bringing the concept of "knowledge kind" to research

Scribner was especially intrigued by the notion of "scientific" and "empirical" knowledge, as conceived originally by Vygotsky (1987). For Vygotsky, the notion of "scientific" referred to knowledge that was "socially constructed", while empirical knowledge was "self constructed" through experience. She believed (like Vygotsky) that the development of scientific and empirical knowledge occur simultaneously, and influence each other, but are analytically distinguishable. Likewise, she believed that knowledge domains could also be analytically distinguished, and that it might be useful to do so for research purposes.

In particular, the differentiation between "formal" knowledge and "empirical" knowledge permitted a number of groundbreaking knowledge elicitation techniques and data analysis methods (see especially Scribner, Sachs, Di Bello & Kindred, 1991; Scribner, Di Bello, Kindred & Zazanis 1992). For example, in the
MRP studies, this distinction allowed Scribner and her associates to hold the body of MRP knowledge analytically separate from empirical processes of production and permitted the exploration of how these two knowledge systems are integrated and overlap within different individuals. It also allowed the development of a method of locating a given individual's understanding of a particular domain and comparing it to that of other individuals.

A notion that is implicit in Davydov's (1988) work and subsequent work on flexible expertise is that true understanding results from grasping the underlying principles or concepts of a given formal domain. When the domain of study is chess, or even Newtonian physics, these foundational principles have been long-identified and are well documented. However, the study of learning in equally formal, but historically newer domains, such as MRP, presents the problem of unidentified underlying concepts. In the course of confronting this problem, Scribner and associates were able to develop a method for representing the underlying concepts of a domain of practice, which was applied to the study of expertise in MRP, but is fully generalizable, so that it may be applied as a method to any domain in need of core concept identification.

In other words, in order to make full use of the formal/empirical distinction between MRP and production, it was necessary to conduct an analysis of MRP as a formal domain in order to isolate its underlying principles. The analytic method used for developing this scheme of underlying and peripheral concepts is described elsewhere (Scribner et al., 1991). Basically it involves a kind of hermeneutic interrogation of the conceptual objects and assumptions of the system's logic. For example, one begins the analysis by asking "what must be assumed to be true for this operation (concept, logical object or relationship etc.) to exist as it does?" The goal was to identify for "newer domains" core organizing concepts like those identified with better-understood domains (such as physics or chess) with the idea that just as understanding underlying principles is implicated in expertise in physics, chess or mathematics, the same might be true in any socially constructed system of knowledge.

In their analysis of MRP, Scribner and her associates identified three organizing principles. These were described on page 9 of this manuscript. Briefly, they are "phased time", "hierarchical item" and "virtual quantity". Importantly, all the logical operations and logical objects in the system derive their basic structure from these, or from the relationships between these.

A comparable analysis was conducted on production knowledge.

However, because systems of manufacturing practice are not formalized, but rather open-ended and content rich, this analysis concerned cataloging the "universe" of concepts generated by all informants at a given site. This universe of concepts was gleaned from ethnographic data and supplemented and clarified using manufacturing texts (e.g., Timms & Pohlen, 1970).

Once the underlying principles and essential aspects of the respective systems were identified, Scribner and associates were able to develop comprehensive conceptual schemes for each knowledge system that represented a kind of collective model of the what-could-be-known. From these they were able to generate a probe battery which included questions and quasi-experimental tasks covering the concepts of both systems. These batteries were extensively tested for comprehensiveness and validity on actual MRP and manufacturing experts and novices.

An analysis of MRP's conceptual structure was especially valuable; besides providing a basis for designing knowledge elicitation tasks, this scheme was important for developing a data analysis method that could examine both breadth and depth of MRP knowledge. For example, it allowed a distinction to be drawn between behavior and speech that pertain to the deeper concepts and that pertaining to the more surface aspects of MRP.

With the conceptual schemes in place, Scribner and associates developed and tested the notion that an individual's speech and behavior, generated while performing MRP and production related tasks, would give some indication as to his or her current conceptual understanding of the two domains and their relationship to each other. The results of these studies (see Scribner et al 1991; Scribner et al 1992; DiBello, Kindred and Zazanis 1992; DiBello 1993, Kindred 1993; Zazanis 1993; DiBello & Glick 1993) show that an analysis of both speech and strategies for the presence or absence of underlying principles allowed a detailed profile of an individual's understanding and allowed researchers to identify an "expert" profile for MRP. This profile could then be used to compare to various kinds of workers' profiles and assist in "locating" an individual's understanding of MRP.

These data also suggested interesting developmental questions (which were not explored in that work). For example, it appeared that, of the three underlying concepts, Virtual Quantity was the first acquired while Phased Time seemed harder and tended to be understood only by those who had a firm grasp of both Quantity and Item concepts. In addition, it seemed that individuals who learned the formal principles of MRP in a "content free" way had difficulty using their knowledge in actual settings (Scribner et al 1991).

Constructive and procedural categories

As indicated in the first sections and as described in greater detail in Scribner et al., (1991), the notion of activity was refined by Scribner and her associates in a way that proved useful to research.

As previously indicated, performing an analysis of subjects' actual job practices made it possible to classify activities according to two important categories, "constructive" and "procedural."

Two types of constructive activity were identified in workplace research done with manufacturing employees (Scribner et al 1992): (1) Job tasks that required employees to create an artifact (such as a report, graph, table or schedule) in order to further inform actions taken; and (2) job tasks which required workers to accomplish specific goals without pre-specified means, causing the worker to develop his or her own means or actions.

In the studies of manufacturing workers using MRP, these two kinds of constructive activity were found to be related to very different ways of thinking about the relationship between the formal MRP system and empirical processes of production. When individuals engage primarily in activities for which the goal is explicit and the actions or operations are left up to the individual to formulate himself, knowledge acquired of the target domain during the day to day accomplishment of goals seems to be more in depth and flexible. When the operations and actions were predetermined and were emphasized over the goal, acquisition of rote procedures is more likely to occur. Therefore, it seems reasonable to assume that activities with clear goals but variable or unspecified means have a different developmental impact than those with clearly specified means and ends.

However, the conceptual MRP studies never clarified the exact relationship between constructive activity and knowledge acquisition. The emergent questions concern identifying what aspects of constructive activities produce this developmental effect. For example, Davydov has indicated that "true understanding" occurs when a learner grasps the relations between conceptual elements in a particular domain (Davydov, 1988). It may be that constructive activities compel the learner to focus her attention on these relational aspects of a domain in order to select appropriate actions and link them to a desired goal. In contrast, learning procedures and "how to" methods compel the learner to focus on the proper sequence and may lead him or her to ignore the underlying conceptual structure necessitating the sequence. In the study described in the following sections, these issues are explored more fully.

A study of the development of MRP's underlying principles

As already indicated, Scribner's work on MRP was carried out in settings where the system had been in place for a few years and no development could be observed. The following sections describe a study of individuals in the course of developing an understanding of MRP's three underlying concepts and was conducted in a site where MRP was just being implemented.

This study is an attempt to examine the relationship between activity and cognitive development in MRP concepts. Specifically, it was designed to test the prediction that among the underlying principles of MRP, participants would experience the most growth in conceptual areas that were introduced through constructive activities. In addition, this study is designed to explore the relationship between general concepts and specific activities and objects by examing how participants solve similar problems with different objects. For example, are general ideas first acquired through understanding specific objects or activities with objects in a different way, or are general concepts acquired in an abstract fashion and then transferred to specific objects and activities?

An additional issue concerns the actual changes that took place with each individual's understanding of MRP concepts. Are there "stages" that can be identified? Is there evidence that understanding is constructivist and emergent, proceeding through an orderly progression with the gradual reorganization of the individual's original notions of Time, Item and Quantity (as these concepts relate to a manufacturing context)? Also is there any relationship between patterns of acquisition and a participant's educational level, job category, computer experience or other factors that might moderate or influence performance or learning?

Clearly it would be difficult, if not impossible, to control the concepts encountered during loosely structured constructive activities occurring naturally in actual job settings. However, it is possible to introduce variations in a controlled manner by engaging workers in simulations of factory life that either afford or restrict opportunities for "constructive" activities of various kinds. Further, it is possible in simulations to control which aspects of a domain are encountered constructively and which are encountered procedurally. For this study, participants learned MRP through a hands-on simulation, or "game" during which core concepts were encountered either procedurally or constructively.

As described in the Methods Section, concepts of Virtual Quantity were presented through procedural activities and concepts of Time and Item were encountered through constructive activities. The following sections detail this study.

Why MRP?

The focus of this investigation on MRP knowledge is not due to an interest in MRP, per se. As shown in numerous studies of expertise the hallmarks of cognitive development in technological domains exhibit themselves at a level of detail unobservable through ordinary methods; thus, a detailed case study offers much in guiding further research and laying out general principles. There are several reasons why MRP is a particularly good candidate for informing a broader program of study. First, as the earlier description suggests, MRP belongs to a class of technologies that are capable of powerful analysis and which recommend actions based on sophisticated formal theories, but can never be made either completely self-sufficient or end-user friendly. Its effective use requires workers who understand the core logic of the computer system and are capable of monitoring its recommendations for action. The activities involved in using the MRP system in context require employees to anticipate what the computer's recommendations mean, and therefore, to "think like" the system.

There is ample reason to believe that the features of the system that require such skills are not unique to MRP, but rather are the unplanned outcome of the state of large-scale computerized tools in general. Exploring one example of a larger trend may begin to map out a qualitatively different kind of cognitive skill than has been studied before.

Secondly, MRP and similar technologies present a paradox that has interesting implications for cognitive development. Previous work has shown that those with considerable production knowledge possess the kind of prerequisite knowledge needed to become true experts of MRP and similar technologies, and yet are more likely to have significant well-developed conceptual assumptions that interfere with understanding of MRP principles; that is, the core "logic" of MRP departs radically from certain key concepts of classical production and for some reason, thinking about production one way may act as an impediment to learning to think about it another way. (This in no way suggests an inherent learning deficit in those who become production savvy. Rather, it may be typical of empirical knowledge domains which are complex and content rich; although knowledge of production processes is generally empirically acquired, such knowledge entails more than "everyday" concepts and considerable experience is required to develop many of the skills needed in factories).

In contrast, complete novices to manufacturing may grasp the core concepts of MRP more quickly, but lack the empirical production knowledge to use it effectively in actual settings. This paradox poses interesting implications for developmental cognition. Clearly, current data (e.g. Di Bello, 1992, Di Bello & Glick 1992) show that some people manage to integrate their production knowledge with the newly acquired MRP knowledge. For these individuals, prior knowledge eventually comes to act as a foundation or bridge rather than an impediment, posing the question: at what point and by what means does the prior knowledge of production stop acting as an impediment and begin functioning as a bridge, or foundation for effective acquisition of MRP? The data show that this level of mastery is not associated with factors such as years of experience, job title or education, but rather with certain factors in the work environment itself and certain aspects of on-the-job activities.

MRP is also a choice domain for another practical, but no less important reason. Following in the tradition of many psychologists who study expertise, I have chosen a domain that I can show demonstrable mastery in myself. Although I originally set out to learn the system in order to do research in this area, I cannot say enough about the mileage that is gained from being able to navigate easily through MRP, converse easily with experts and intuitively know when to probe deeper during interviews with participants at all levels. Having passed through the struggles of many of the learners I feel comfortable in my ability to focus observations on "key" indicators of transition and to recognize milestones of development in this area.

METHOD

METHOD

This chapter describes the participants, the "starship factory" workshop intervention (the introduction of "constructive activities") and pre workshop and post workshop performance probes used for this dissertation to track conceptual shifts as evidenced in the participants' strategies. The methods for analyzing the strategies participants exhibited while doing the performance probes are also discussed along with a description of the analysis used to identify and isolate patterns among strategies that might indicate transitions in conceptual understanding. The descriptions of the participants and the starship factory workshop are brief as both are discussed fully in Appendices C and D.

Participants:

Participants came from three job categories of the New York City Transit Authority Overhaul shop, the division of the Rapid Transit portion of the NYCTA that re-manufacturers the subway cars and its major components (such as motors). Unlike the repair and maintenance divisions of Rapid Transit, this shop functions more like a factory, producing finished cars and large components in order to supply both the fleet and the maintenance shops. The titles involved in this study are: Air Brake Maintainer (ABMs, who are unionized mechanics), Supervisors and Managers (salaried and non-union), and Analysts (a general office position for those involved in planning and special projects). All participants were drawn from a pool of Transit Authority employees who volunteered to participate in the MRP workshops. The volunteers were solicited by an elected Union Shop Stewart rather than by management. This method was decided upon after the researchers met separately with union representatives and management staff. A representative from the union circulated a list of all personnel and individuals indicated interest by placing a check next to their names. All of these volunteers expected to have their jobs affected by the planned MRP implementation and for many, the starship workshops would be their only form of introductory training.

A major assumption of this dissertation is that knowledge does not occur in isolation from context and social meaning and that "development" or change in ways of thinking or knowing must also have some grounding in systems of meaning. Although these socially engendered and maintained systems are not the focus of the inquiry reported here, some understanding of the organization of work and common practices was needed in order to refine the workshops used for the study. In addition, the information gathered was essential to analyzing the data. As indicated in Appendix D "NYCTA Overhaul; basic organizational description", considerable hours were spent doing shop floor observations and interviews with various personnel (often while they worked) in order to more fully understand the duties and responsibilities associated with various job titles and functions, as well as to tease apart the difference between "official" job descriptions and actual responsibilities and pressures of various jobs. What follows is a brief version of the more detailed description in Appendix D.

ABMs are hourly employees who are trained mechanics with various educational backgrounds. About half of the participants entered the TA as "car cleaners", after taking a qualifying civil service exam. They received their mechanical training through the TA's "18 month program" a full time 18 month training program that instructs qualified applicants in air brake maintenance and repair. The other half had considerable mechanical work experience before coming to the TA and did not go through the 18 month program. For example, many came from the aviation industry. ABMs are mainly responsible for disassembling, cleaning and remanufacturing the components of the air brake system and the compressor units. "Officially", they are ignorant of the long term schedule or plan for production. They are also not required to think about costs, material availability or consequences of inventory mismanagement or other work flow issues. However, observations of shop floor practices indicate that they are implicitly accountable for their material practices but are not permitted the tools (such as access to computers or schedules) for anticipating future work demand. Literally, they get their orders in the morning and are required to do the day's work as issued by the foreman, by whatever manner they can. Several behaviors observed on the floor indicate that shop floor personnel do, nonetheless, anticipate future work demand and give a great deal of thought to what might be required to keep the fleet running. For example, many ABMs "hoard" parts in lockers or private storage places, and the hoarding patterns indicate that they have some notion of a natural schedule of demand. For example, certain parts are stocked away if a harsh winter is anticipated or if other patterns of part usage are observed. The informal "scheduling" of material on the part of ABMs is largely unrecognized or unacknowledged by management.

Analysts do the official schedule, both short range and long range. As detailed in Appendix D, planning managers readily admit that these schedules are often not made in a coordinated fashion, and that there is no reliable feedback mechanism for ascertaining if a given forecast or schedule was actually reasonable or not. This may account for the TA's practice of recycling purchasing and production schedules from year to year, whether they have actually met demand or not. In addition to the schedules, the analysts are engaged in the research necessary to acquire the materials needed for production and to meet changing safety regulations. They investigate new products, new designs for common items (such as door switches) and new vendors. In addition, they identify the items needed for and costs associated with various overhaul programs or replacement programs.

Supervisors and managers are required to keep the unionized hourly workforce occupied, schedule the needed skills on appropriate shifts, meet the schedule as it comes down from the planning department and handle unplanned demand. They spend much of their time trying to find the material that will help them actually meet the schedule and deal with various material shortages, usually created by unplanned demand (e.g., cars that break down or are involved in accidents). Since TA overhaul is mainly reactive and crisis oriented, it accomplishes its goals at great financial cost; acquiring materials on short notice or overbuying to prepare for unplanned demand or poor schedules greatly inflates the cost of doing business.

All participants were aware that the MRP system would be reorganizing the priorities of the shop to be more cost efficient and more pre-planning oriented. Most were unclear about how their jobs would actually be affected.

Pre-testing using performance probes

Prior to participating in the workshops, each participant filled out a form with information on previous work history, formal education, computer experience and MRP experience. This form is included in Appendix A (Probe and interview materials).

Participants were then interviewed about their current responsibilities, their notions of manufacturing, and asked to do a number of performance tasks (also included in Appendix A) that elicited their strategies in response to a manufacturing task. The latter (performance probes) were used for this dissertation and are discussed in more detail below. Versions of all probes used had been thoroughly tested for their ability to predict MRP knowledge on both actual experts in MRP and in previous studies of MRP learning (Scribner et al 1991; Scribner et al 1992). Generally, they were developed to tap into workers' understanding of key MRP and manufacturing concepts and were constructed to invite a variety of strategies. Table 1 shows the probes used for this dissertation and the underlying principles that they targeted. Probes that tapped into more than one concept (largely unavoidable given the intertwined, embedded nature of MRP logic) were constructed to target one concept more strongly. The concept list shown in Table 1 indicates which concept is being primarily targeted in each probe.

All interviews were audiotaped and participants were encouraged to talk aloud while working or explain their strategies to the interviewer while working.

The Probes

1. Scheduling "A"

"Scheduling A" involved the scheduling of all production and purchasing activity to make 200 of a fictional, abstract item, for shipment in August. As can be seen from the sample problem (Appendix A) participants were given a calendar, information about the item and all of its parts (including vendor and production lead times), a BOM (i.e., Bill of Material or the data file containing the item-hierarchy) and certain constraining conditions. The participant was asked to write the complete schedule on the calendar and explain all decisions. The interviewer used a clinical interview method, asking the participant at various points the logic behind various scheduling decisions. A sample of the interviewer/interviewee dialogue is shown below.

Interviewer: I noticed that you started in the August

> box and then started counting back. That's very interesting; why did you begin there?
> Interviewee: I am trying to allow enough time for the parts to arrive. I added up all the lead times from the BOM, and I'll begin on the date of the longest lead time.
> Interviewer: I see. What made you think of adding up all the lead times?
> Interviewee: Well, it doesn't make sense to start as early as January, to me. So I want to know what's the latest I can start and still have enough time.

2. Card Sort

On this task, participants were asked to "make an item" using the cards. It was explained to the partcipant that all the cards represented a complete item and that the participant should use her imagination to arrange the cards into a sensible array representing the whole item and its parts. As can be seen from the sample set in Appendix A, these cards did not represent a readily identifiable item. It represents the coded names and stock numbers of an item (and its parts) made in a hardware factory, but for purposes here, it was regarded as an "abstract" unknown, since it could not be recognized or decoded without knowledge of that hardware factory's coding system.

As the participant sorted, the interviewer asked, again, for explanations and reasons for the strategy as it evolved. These conversations were recorded. At the end of the sort, the interviewer copied down the participant's array. All participants were asked if they wished to do it a second time, using a different strategy.

3. Tree Question

The tree question required participants to calculate the number of "things" needed to complete an order of 20,000 "A's", another abstract unknown item. The sample in Appendix A shows that this required participants to coordinate the notion of relative quantity with the notion of "item". There are various correct answers to this question (e.g., 40,000: 20,000 each of B and C; 120,000: all purchased parts) depending on a number of various conditions. In addition there are certain wrong answers that would indicate clear misunderstanding of what the diagram means (e.g., 180,000, the sum of all parts on all levels, as if there is no inherent redundancy in MRP item hierarchies). Again, participants were asked to give an answer (or more than one) and explain how the calculation was done and logic behind it.

Workshops:

The workshops used with participants were developed after months of analysis with the help of an MRP expert and others familiar enough with MRP logic to recognize activities and behavior that most richly represented the underlying logic of MRP systems. The exact content is described more fully Appendix C "MRP workshop; two days of being a computer". Below is a brief summary.

Originally, the study had been designed to include "procedural" and "constructive" workshops; those who engaged in the "constructive" workshops would be the experimental group, while those who participated in the "procedural" workshops would comprise the control group. Because the participants were depending on the workshops for actual training, it was decided that the original study design had to be altered. However, as previous research indicates procedural activities do not lead to in depth understanding, there was a risk that half the volunteers would be at a professional disadvantage after the workshops. Because this risk was unacceptable to our volunteers, the workshop was re-designed so that specific MRP concepts would be introduced through procedural activities for all participants, while remaining concepts would be introduced through constructive activities. Therefore, rather than compare conceptual change between individuals, changes in the three concept areas were compared within individuals.

Previous work in MRP learning shows that, of the three underlying principles, the notion of "relative" or "virtual" quantity is acquired first while "phased time" is acquired last and is reported to be the most difficult to grasp (Scribner et al 1991; Scribner et al 1992). It would follow that, if constructive activities have a special capacity to shape development, excluding constructive activities having to do with Relative or Virtual Quantity should alter this normally observed trend.

After considerable piloting, the workshop included equal numbers of activities that would constructively engage participants with MRP's way of thinking about objects and parts (hierarchical items) and its way of thinking about time (phased time). Numerous "procedural" activities exposed the participants to concepts of "virtual quantity" and, in as much as it was possible, constructive activities exposing the logic of "virtual quantities" were avoided. This was difficult do for two reasons. First, because of the intertwined nature of the underlying principles in MRP, it is very hard to begin to understand Phased Time, for example, without getting a sense of how this will affect quantities. Secondly, MRP is very quantity intensive; because all the mathematical calculations were done manually by the participants, actual "practice" time with virtual quantity algorithms was greater than time spent practicing activities related to other concepts. However, the workshops were carefully designed so that participants were not "constructing" or inventing an algorithm for calculating virtual quantities. This was done by having all participants do the calculations using the MRP worksheets (see Appendix C: workshop materials) which required participants to do all the math manually, but which greatly constrained what they could do. The lecture material and workbook text covered all concepts equally.

The idea here is that if constructive activity simply stimulates overall development in all MRP concepts, the same pattern of development seen in less structured environments (as seen in other studies) should repeat itself, but may occur in less time. If constructive activities have a special effect, development should be either a function of activity entirely -- with no evidence of normally seen sequences or trends -- or any stage-like development should occur within the conceptual areas that have been introduced through constructive activities.

Below is a schedule of activities conducted over the two day period and the target concepts surrounding each activity. Greater detail on all these activities is provided in Appendix C.

Day One:

1. Introduction to the starship factory and its goals
2. Organizing a planning and production system
3. The game begins; running the factory for 6-8 twenty minute periods
4. Discussion: What happened; let's take a look at our plan, our resources and compare it all to what the previous owner would have done. What is the strategy we defaulted to?
5. Lecture and Slides: Inventory concepts, MRP concepts.
6. Discussion: Maybe there is an alternative:
   MRP -- what it does
   MRP -- what is requires: BOMs, Item Masters,
7. ITEM Activity: Exploding the ship/inventing an item structure
8. ITEM/TIME Activity: Creating Item masters as a way of telling MRP what to think about/when to think about it.
9. ITEM/TIME Activity: Constructing BOMs that make MRP sense

10. TIME Activity: Putting a master schedule on the Item master worksheets that will allow the system to recommend a plan

Day Two:

11. Quantity Activity: Entering in the "on hand" and "on order". Doing the calculation (regeneration) the MRP system does when it regenerates its recommendations using your master schedule.
12. TIME/ITEM/QUANTITY Activity: Translating the plan that MRP generated into a "buy" and "build" plan for the next eight weeks.
13. Building according to this plan

14. Calculating assets again.
15. Discussion: Comparing the first plan and its results to the new plan. What is different? How was it to build according to the second plan? What has changed?
16. Discussion: Improving upon the new ways. MRP is somewhat rigid; how can that be dealt with?

Macola Inc. (the MRP software package that the TA decided to use) agreed to donate a copy of the system for research purposes. The system was installed by the vendor on the university's central LAN. All workshop activities were checked against the finer points of the logic as it is represented in this system. Although all MRP systems are built upon the same theoretical assumptions (Orlicky, 1975) different software packages have slight variations in formulas or BOM structure. Great care was taken to ensure that the workshop activities could be reproduced using the participants' version of MRP. In addition, the system was used to calculate "ideal outcomes" of workshop activities for use as feedback to participants (see samples of MRP system output in Appendix C). Once the TA's system was installed, dial-in access was arranged so that the researcher could communicate via email with participants and observe any changes being made in their MRP system (such as the input of data, setting up of file structures, etc.)

Post-testing

Post-testing was conducted about two months after the workshops. It was expected that by then any rote learning that had taken place would be forgotten and MRP strategies exhibited by the participants would reflect what they had actually come to understand about MRP. According to the original technology implementation plan, all participants were expected to have equal exposure to the actual system during the period between their workshop experience and post-testing. However, changes in management strategy provided certain individuals with considerably more exposure. These individuals will be discussed in more detail in the Results section.

As can be seen in Table 2. and Appendix B (probe materials), the post performance probes were structurally similar to the pre-tests but applied to more kinds of objects. These tasks again elicited strategies that would reveal understanding of MRP and Traditional Manufacturing principles. However, this time, multiple versions of the scheduling and card sort tasks were given to ascertain how firmly the new knowledge had rooted and whether specifics from the activity with the starship would influence performance. A Latin Square order was used to randomly assign the order of the tasks for each person.

Scoring

Each performance probe was scored for the presence, partial presence or complete absence of 10 to 12 different strategies that have been shown in other work to be associated with in depth understanding of MRP concepts being targeted. The same performance profile was also scored on five typical manufacturing strategies shown in other work to conflict with the acquisition of MRP concepts. Therefore, each protocol got an MRP score and a Traditional

Manufacturing score. Table 3 shows some sample strategies that have been shown to indicate MRP or traditional manufacturing thinking. Not all probes afforded the expression of all strategies (for example, the card sort did not provide any opportunity for "back scheduling"). For a complete list of strategies afforded by each probe, see the score sheet set in Appendix B. This appendix contains a complete set of coding forms, a coding manual and some samples of typical participant strategies and how they were scored along with samples of the participants' talk while performing.

Scoring was based on the participants' pencil and paper work and their explanations for their strategy. Talk was used mostly to clarify ambiguous problem solving strategies. As can be seen from the Coding Instructions and the samples in Appendix B, the coders were required to score a "1" if a particular strategy or behavior was observed and a "0" if it was not. These coded forms of "0's" and "1's" were then used for further analysis of overall strategy and patterns among sub-strategies. These analyses are described below.

Reliability of the coding scheme was tested using a blind coder, who had no familiarity with research of this kind, but who was accustomed to scoring performance items (a clinical psychologist). This individual coded five participants on all performance measures, using the forms and instructions in Appendix B and transcripts of the talk from the interviews (transcripts used were of the participants' talk during the target performance probes). Agreement between coders was 92% across all probes. Disagreements usually concerned the interpretation of calculation errors on the part of the participant (e.g., is this a case of adding wrong or misunderstanding the concept?) and were resolved by examining a given behavior in the context of the whole strategy. Once procedures were finalized for coding such errors, the author coded the remaining protocols.

Data Analysis

Analysis of Scheduling probes for evidence of Overall MRP and Manufacturing Strategies

The "scheduling" tasks were designed to elicit the participants' overall MRP and/or traditional manufacturing strategy. These probes allow the participant the opportunity to do what manufacturing management systems actually do, schedule purchasing and shop floor activity for specific numbers of multi-part items in order to meet specific future deadlines. As indicated, on each of the probes manufacturing and MRP behaviors were scored using the forms and instructions in Appendix B. Then for each task, the total number of "traditional manufacturing" and "MRP oriented" strategies each were added up (i.e., all the "1's") giving both an "MRP total" and "manufacturing total". These numbers were then divided by the total number of possible behaviors for each category, giving a proportional score for each domain. For example, if a participant showed 8 out of 12 possible MRP strategies for a given task, the scorer would have given him 8 "1's" and 4 "0's". To get the participant's proportional score, 8 is divided by 12, giving the participant a ".67" for MRP, for that probe. The manufacturing score would be calculated the same way for the same protocol. These scores rendered a gross picture of general strategy in each domain, or the replacement of Manufacturing strategies with MRP ones. From here on these scores are called the "aggregate" MRP and Manufacturing scores because they deal with all the MRP or Manufacturing strategies used on a task, rather than specific MRP or Manufacturing strategies related to specific concepts.

As can be seen from tables 1 and 2, the pre-test contained one generic scheduling question, to ascertain if individuals had any MRP strategies at all. During post-testing, three versions of this task were given: the original generic version (an abstract unknown object) a more complex version with the ship (with which the participant had extensive "constructive activity" experience) and an equally complex version with a common, familiar object -- a button top pen (with which the participants had much experience, but no "constructive activity" history). Therefore, a total of four MRP and four Manufacturing scores were obtained for each person on scheduling probes.

A similar analysis was performed on the data from the card sorts (one pre and two post sorts). A total of three MRP and three Manufacturing aggregate scores were obtained for each person on the card sorts.

<u>Analysis of data for recurring patterns</u>

Aggregate analysis of scheduling probes rendered information about overall growth, but not about specific behaviors that might indicate shifts in understanding specific concepts. The "0s" and "1s" were re-analyzed for recurring patterns. Three salient patterns were further coded.

1. Symmetrical card sorting

The first of these patterns was a tendency for some participants to do "symmetrical" sorts when making item structures with the cards. Symmetrical item structures rarely occur in actual systems and these participants had never seen any examples of symmetry in item representations.

Importantly, all cards have sufficient information in equally salient lettering to sort cards correctly according to both their vertical and horizontal relationships to each other. A symmetrical sort is possible only if one ignores the "goes into" information, which would indicate its vertical relationships to other cards. The data from the card sort coding forms for each participant were thus used to re-code for "symmetry" patterns. Specifically, in the re-coding, participants' strategies were coded as "pre-sym" if a participant did not produce a symmetrical sort because the overall sort precluded any symmetry (e.g., they did a linear "assembly" line sort with no levels). The sort was coded as "Symmetrical" if they produced a symmetrical sort, (resembling a pyramid) that also accurately represented each card's horizontal level, but with no regard to each card's relationship to those above and below it. Lastly, the sort was coded as "MRP-asymmetrical" if no symmetry was produced because the participant had used the vertical orientation information and was coordinating each card's vertical and horizontal relationship to the other cards. In other words, it was coded "MRP-asymmetrical" if the sort was MRP-correct.

2. Lead Time's relationship to parts and wholes

Further examination of the data indicated patterns among the Phased Time strategies. Therefore, phased time concept portions of the coded data forms for the scheduling questions were re-coded for this subtlety. For each of the scheduling questions, the coding instructions indicate that if Lead Times are not calculated according to strictly correct MRP principles, further coding is done on the type of lead time represented. The patterns among the "0s" and "1's in this portion of each protocol were thus re-coded as follows. If the participant had no lead time concept, the strategy was categorized as "NR"s for no relationship to lead time; if she or he showed all part's lead times as being relative to the end item only (as if it were the only parent item) rather than relating lead times to "true" parents, the strategy was coded as "PW" (parts related to wholes only) meaning that lead time is represented as relative to the end item only. If the participant represented some concept of part-part phased time relationships, but had some of the parts inappropriately relating to the end item only, he or she received a "PWp" for complete part/whole representation with partial part/part representation. (This usually was indicated by a "1" on the coding form for either "Appropriate but with some miscalc" or "appropriate but too short"). Lastly, A "PWP" was given if the participant had all phased time relationships represented correctly, showing perfect time phased calculations for both part/whole and part/part time phasing.

3. Many -> One before one->one

Participants also made another, systematic error. Many participants' strategies showed that they understood that, within the representation of an object, the many parts that make up a whole are represented as themselves, individually, and that the representation of the "put-together" piece is understood by MRP as a separate object (even though, in fact, it is not). However, many of those same participants had not grasped the functionally equivalent notion that a single object that has undergone a change also needs to be represented as two distinct things in MRP even though, in fact, it is the same object. The coded forms were re-analyzed for patterns between these two behaviors, using the "Appropriately shows redundancy" data on scheduling probes (see Appendix B; scoring forms for scheduling probes). Participants had been given a "0" for both the categories "many to one" and "one to one" if they did not represent any part -> part relationships on their schedules. If they represented any part->part relationships at all they were then scored separately (1 or 0) on the accuracy of their one->one relationships and many->one relationships. In the re-coding, participant performance was classified as "does not represent either many->one or one->one"; "represents only many->one"; "represents only one->one; "represents many->one and one->one".

Correlation Analyses

The work and educational history forms filled out by each participant were used as data on each participant's age, sex, educational background, computer experience, MRP experience, years of experience in their current field, and years of experience at the TA. Pearson correlations were performed between the various categories of patterned response (e.g., symmetry) and all demographic information; between educational background and aggregate MRP and Manufacturing scores; and between computer/MRP experience and aggregate and trend marker scores. The idea was to examine the relationship between pattern of response and education and/or work history.

RESULTS

RESULTS

A comparison of each participant's post test performance with pre-test performance showed three trends. First, workers as a group showed that they had replaced their traditional manufacturing strategies with MRP oriented ones rather than simply added MRP strategies to their repertoire. Secondly, certain consistent patterns of error or "misunderstanding" indicate some support for the notion that participants were coming to understand MRP by "constructing" a kind of mental model of it and its relationship to real world manufacturing and that this model underwent certain systematic shifts. Specifically, the process seemed to be one of reorganizing knowledge through a process of deconstruction/reconstruction of existing ways of knowing. In particular, some "errors" appear to be transition markers, predicting new ways of understanding about to emerge. Thirdly, analyses of groups and individual differences showed that participants with different work histories may be "coming to" a similar understanding of MRP concepts but through very different paths, i.e., reorganizing different initial ways of knowing.

Scheduling Probes

In general, traditional manufacturing strategies were replaced with MRP strategies after the workshops. This was shown most clearly on the "scheduling" tasks. As noted in the Methods chapter, these probes invited the most comprehensive MRP and/or traditional manufacturing strategies. Tables 4 and 5 show aggregate MRP and Manufacturing performance scores from the "scheduling" probes for each participant and for each version of the scheduling probe. Table 6 presents a summary of the pre-workshop and post-workshop means among groups. As indicated in the Methods chapter, each participant received both an MRP and Manufacturing Score for each task. Each of these "aggregate" scores represent the proportion of total possible MRP or manufacturing strategies used to generate an answer. E.g., a fully mixed (MRP and Manufacturing) and fully comprehensive set of strategies in each domain could result in an individual getting a "1.0" for both MRP and Manufacturing on the same task. These proportional scores are called "aggregate" because they are calculated without regard to the pattern of strategies within participants, only their presence or absence.

Results on these tables show that overall knowledge of MRP concepts increased on the whole while traditional manufacturing strategies diminished after the workshops. The pre- and post-workshop differences were found to be significant for all workers as a group, $F(1, 30) = 6.79$ $p.<001$. In fact, the post workshop scores were found to be somewhat higher than expected and comparable to those seen in plants where the system had been fully functioning for at least 2 years (Scribner et al 1992). This is especially interesting given that many participants reported that they could not remember how they had done it before or could not replicate their previous approach (although participants were not required to try to do this).

As can be seen by comparing Table 4 and Table 6, among the three job categories, supervisors began with the most initial MRP knowledge, as a group, but this was largely attributable to two individuals out of four. Analysts showed a wider distribution of relatively high initial MRP knowledge. Air Brake maintainers averaged .13 before the workshops. An ANOVA comparing only the ABMs and Analysts indicate that these groups differed significantly, $F(1, 28)=11.3$, $p < .002$. (Given the small size of the supervisor group, they were not included in statistical analyses of between group differences.) The tendency for analysts to show greater knowledge of MRP concepts, as a group, corresponds to their job responsibilities; many are planners and schedulers and some have worked in MRP environments before. After the workshops, analysts showed higher average aggregate scores for MRP knowledge overall, averaging .75, with a median score of .82, but the least growth, given their beginning average. Air Brake Maintainers achieved aggregate scores somewhat lower than analysts after the workshops, with an average of .67 and a median score of .75. This was comparable to the average of MRP aggregate scores shown by supervisors (.69). An analysis of variance comparing the ABMS and Analysts indicate that these post-test differences were not significant.

Although differences in aggregate performance are not statistically significant, the sources of difference have interesting implications. The post-workshop difference between the two groups were due largely to one version of this probe. An analysis of variance comparing the Analysts' and ABMs' performance on the "Abstract unknown" alone after the workshops did show significant differences between the two groups, $F(1, 30) = 6.09$, $p < .02$. ABMs as a group seemed to have difficulty with "post unknown abstract", which was a far simpler scheduling task (with three parts as opposed to the starship's 13 parts) but which was abstract rather than concrete or "contexted". When scores for this probe are not used in the calculation of averages, group differences disappear, with ABM's averaging .71 and analysts averaging .75. This suggests that, while the two groups are performing similarly overall, they have acquired this strategy through different paths.

Manufacturing strategies on scheduling probes:

On manufacturing strategies (see Table 5 and 6) Analysts averaged .52 before the workshops, while ABMs averaged .80. Supervisors averaged .53, but as can be seen in Table 5, they showed great individual variation. As before, significant differences were found between Analysts and ABMs on the pre-tests, $F(1, 30) = 11.31$, $p < .0001$.

After the workshops, the average among ABMs was .25 (among participants who completed all tasks), while supervisors retain a relatively high .42 and analysts showed an almost complete absence of traditional manufacturing strategies (mean is .06 among those who completed all tasks, and .13 including the two who did not). However, these differences between ABMs and Analysts were not significant. In general, most participants showed diminished use of traditional manufacturing strategies and increased use of MRP dominated strategies.

Integrated Strategies:

A few individuals showed an interesting deviation from the trend toward replacement. These participants attempted to produce scheduling solutions that integrated both MRP and traditional manufacturing strategies. On Table 4, these results are marked with an asterisk. Those who attempted this consistently (on more than one post-workshop scheduling task) were Supervisor 3, and ABM 7. (Supervisor 2 and ABMs 5 and 6 attempted this on the starship schedule only). A closer look at all five of these scheduling strategies reveals a rather sophisticated attempt to integrate plant and labor capacity considerations into their scheduling solutions. For example, although these individuals showed the "backwards time" scheduling strategy inherent to an MRP strategy, they attempted to spread out requirements evenly to accommodate plant or labor capacity. Capacity is one real-world aspect of scheduling that MRP cannot consider. In previous work, this kind of integration is an indication of rather sophisticated understanding of MRP concepts and the system's relationship to actual production and can take considerable time to develop (Scribner et al 1992; Di Bello & Glick 1993).

Not surprisingly, the post-workshop interviews revealed that these five individuals were among 7 who had begun to use the system at least on a weekly basis in a pilot project to schedule the work in their division of the Pneumatic shop (compressors). Observations indicate that these activities were largely "constructive" as they involved setting up a new system without pre-set procedures. Supervisor 3, on the other hand, showed considerable MRP knowledge before the workshops and no manufacturing strategies (on the scheduling task). His subsequent experience with the system is not known.

Supervisor 3's profile suggests that replacing traditional manufacturing strategies with MRP strategies might precede integrating the two approaches. He moved from an MRP dominated approach to a more integrated one. This may have been what occurred with ABMs 5, 6 and 7 and Supervisor 2 in the period between interviews, but this cannot be known for certain. However, the profiles of these four do suggest that constructive activity after training might continue a general developmental trend begun in the workshops. This is further suggested by the complete absence of integration among the analysts, who have no opportunities for seeing how schedules are implemented on the floor.

<u>Card Sort Tasks</u>

On the card sort tasks participants showed trends similar to those exhibited on the scheduling tasks. For most participants, MRP strategies came to replace traditional manufacturing strategies during post testing. That is, rather than sort cards according to traditional notions of goods either assembled from clusters of related parts, or related along a linear assembly dimension, participants were more likely to construct something like an MRP "top down" hierarchy. (See Appendix B for samples of "traditional manufacturing sorts" and "classic MRP" sorts with attached coding forms.)

However, the results from these tasks must be interpreted more conservatively as this probe tested mainly for participants' grasp of "hierarchical item".

Tables 7 and 8 summarize all the aggregate scores for all participants on MRP strategies and Manufacturing strategies respectively (these were coded separately for the same task, as with the scheduling probes). Pre-test averages showed no significant between-group differences. During post-testing significant between group differences were found between ABMS and Analysts on all overall averages for all tasks, $F(2, 30)=3.9$, $p<.02$). As with the scheduling probes, this difference was largely due to the analysts' greater average scores on the "abstract unknown". On this task alone significant between group differences were found ($F(2, 30)=5.03$, $p<.01$) while no significant differences were found with the starship card sort alone when analyzed separately.

Integrated Card Sorts:

As with the scheduling probe, card sorts revealed a few individuals with "integrated sorts" (see Appendix B for examples). These sorts are marked with an asterisk on Table 7. Unlike integrated schedules, integrated card sorts are much harder to interpret, as they may reflect an incomplete understanding of MRP item structures and a tendency to default to manufacturing-influenced methods of classification. Because a scheduling probe incorporates all the major concepts of MRP, (while the card sort taps into the concept of "Item") it is much clearer when an individual is generating an integration of two approaches. Therefore, the protocols were examined again to see if the individuals who generated "integrated" sorts had also generated a "classic MRP" sort, showing understanding of MRP's item hierarchy (as noted in the methods chapter, each participant was given the opportunity to generate two sorts during each interview). Table 7 shows a double asterisk beside the names of those individuals who generated a classic MRP sort during the interview, and also produced the "integrated" sort during their second attempt, as their "preferred" way of doing it. As can be seen when comparing Tables 4 and 7, these same participants were among those who had also generated "integrated" strategies on the scheduling probes (SUP2, SUP3 and ABM7). As mentioned, SUP2 and ABM7 had been working with the system in a "constructive" manner (setting up data files and defining objects and operations) in the period between interviews. Post workshop interviews also revealed that ABM8 had also been working with the system in the time between interviews and after workshop training. This further suggests the importance of constructive activities in the further development of MRP into an integrated understanding of MRP's relationship to production.

The results reported so far have been on specific probes. The following analyses and results concern patterns of response across the performance probes. It is clear that all participants changed and moved toward increasing "MRP-like" strategies, and in some cases a sophisticated integration. As will become clear, examining patterns across probes reveals both differences and commonalities in the manner in which individuals arrived at similar points in understanding.

<u>Uneven change in the three organizing principles.</u>

As predicted, the learning did not occur evenly among areas covered by the workshop. As indicated, the workshops were constructed to provide extensive practice with the notion of "relative quantity", but participants were given specific MRP calculation procedures and were not encouraged to invent or explore MRP algorithms for obtaining virtual quantities. In other work, of the three organizing principles, virtual or relative "quantity" is usually shown to develop first and is generally considered the "easiest" MRP notion (Scribner et al 1991) when learning is either incidental or classroom based. This did not happen here -- in fact quantity was the weakest -- suggesting that constructive activities can influence the concepts that develop.

Table 9 shows relative performance in the three conceptual areas and the probe data scored. These data are percentages of participants, taken from several probes, as noted. As can be seen, the fewest participants achieved a truly flexible notion of Virtual Quantity. In addition, all participants who came to understand Virtual Quantity also developed a thorough understanding of Phased Time and Hierarchical Item while many who became adroit with Phased Time and Hierarchical Item did not come to understand Virtual Quantities.

<u>Understanding of Virtual Quantity, as measured by the "tree probe"</u>

Participants' lack of development with "virtual quantity" is further shown in participants' performance on the "tree" probe, a performance task much tested in previous MRP studies and designed to test for understanding of how MRP calculates Virtual Quantities (see Methods Chapter, p. 50). Table 10 shows the performance of participants on the "tree" probe, which measured participants' ability to calculate a variety of Virtual Quantities. Table 10 shows all the possible calculations for this task and the percentage of participants who gave each answer. "Adds all = 180,000" indicates no concept of how MRP calculates quantities and indicates a typical traditional manufacturing strategy. "Grasps partial redundancy 140,000" indicates that the individual realizes that some of the parts on the tree are actually assemblies of other parts and need not be counted twice. "Grasps full redundancy 120,000" indicates that the participant realizes every part that undergoes a change before the final assembly need not be counted twice, but being able to give <u>only</u> this answer indicates that the individual does not yet realize that the "what" that gets counted can be relative, and a variety of answers are possible. "Can give a variety of correct virtual quantities" indicates that the participant realizes that there is no one answer to this task and in fact several answers are possible. This indicates a fully flexible notion of virtual quantity. As can be seen, only two people were able to do this during post-testing (6%).

Overall "concept profiles"

Lastly, the uneven development is shown in patterns of concept acquisition among the participants across several tasks. Table 11 shows these patterns. The percentages shown indicate the percentage of participants who possessed a specific profile of concepts. As can be seen, only 6% showed full proficiency of all concepts on all tasks, although 15% showed proficiency on components of all probes having to do with both Phased Time and Hierarchical Item. More importantly, all those who developed the concept of Virtual Quantity also developed an equal understanding of Time and Item concepts. However, many who showed an impressive understanding of Time and Item did not develop commensurate Quantity concepts.

"Error patterns" as stage markers

Aggregate analysis of scheduling probes rendered information about overall growth of MRP strategies, but not about specific behaviors that might indicate shifts in understanding specific concepts. A closer analysis of the coded behaviors on all probes revealed patterns that may, in some cases, indicate evidence of developmental stages, although clear cut stages cannot be definitively established from these data. Rather, three systematic errors or patterns suggested stage-like development "within" concepts and, more importantiy, that participants were "constructing" MRP for themselves, rather than superimposing a transferred understanding. However, constructive activities maintained interesting effects. Presented below are the data suggesting stage-like development and the interaction of these stages with constructive activity effects.

Symmetry as it relates to concepts of hierarchical "item" structure:

The most robust "error" pattern showed up in a tendency for many participants to do "symmetrical" sorts when making item structures with the cards.

It seems that when participants first begin to understand the notion of items as organized according to hierarchical, redundant level structures, they grasp the item's relationship to its horizontal level before they understand the relationships of items to each other, between levels, along a vertical dimension. Both the horizontal and vertical orientation present a complete reorganization of how traditional manufacturing models represent item relationships. This type of structure is in contrast to traditional manufacturing, where items are typically represented in relation to the finished good in a kind of "cluster" relationship.

This partial understanding -- grasping the horizontal but not the vertical -- leads to an interesting systematic error in the "card sorting" task. Rather than sort the cards into an item hierarchy that considers both level and what the item is either going to become or go into, participants make symmetrical pyramids. Figures A and B show the difference between these two different sorting patterns. This is a particularly interesting result since the information needed to place the cards correctly (both vertically and horizontally) is clearly and equally represented on the cards. Participants seem to be ignoring the "goes into" information while attending to the "level" information. This is also interesting because such symmetrical "pyramids" are virtually non-existent in actual MRP structures and there are none in the participants' workshops, training materials or work materials. In other words, they are invented by the participants. The data from the card sort coding forms for each participant were thus used to re-code for "symmetry" patterns as described in the "Methods" chapter.

Table 12. shows the percentage of all participants exhibiting symmetry or asymmetry on pre and post card sorts. These results show the ubiquity of this pattern. Close examination of individual profiles strongly suggests a transitional function for symmetry. In nearly all individuals, symmetry occurs as a precursor to grasping the vertical dimension of item relationships in item structure. For example, if a participant sorted symmetrically on her pretest (showing a horizontal but not vertical understanding of levels) in all cases this error was resolved by post-testing. In participants who showed no notion of item structure in pre-testing, the notion first appeared as a symmetrical sort. This sequence was never reversed in any individual's data (although one participant reverted to symmetry on one post-card sort, and not the other). See Table 13 for the sorting patterns across all card tasks and percentage of participants that exhibited each pattern. A chi-square was performed comparing the patterns of invariant and variant sequences among all participants with the expected even

distribution of invariant and variant sequences among a group of the same size. A chi square revealed the distribution of invariant sequences was found to be highly significant (p.< 00001).

Most interesting however, are the differences in symmetry behavior between the two post test card sorts. One "card sort" represented an unknown object, abstractly represented and impossible to identify. The other represented the ship that participants built and invented planning methods for during the workshop. Both sets of cards contained the information needed for horizontally and vertically correct MRP sorts. Table 12 shows that 47% of the participants showed symmetry when sorting the unknown object while performing a completely correct sort for the ship, suggesting that these participants could only exhibit their full understanding of "item" with the object they had learned MRP through. In most cases, participants were not aware they were using different strategies, or if aware, they could not correct the symmetry in the unknown object even though they were aware of what information was important! The example dialogue below from a participant that sorted the starship cards using the "goes into" information correctly and yet produced a symmetrical sort on the "abstract unknown" illustrates this discrepancy.

> ANA3: (after sorting the "unknown object" cards symmetrically) I know that's not quite right, but I don't know why.
> EXP: Well, I don't think you did the starship cards the same way. Were you thinking different things?
> ANA3: Yeah, I mean, I know I should do something

> different, Level, one, level two, that's all right.
> EXP: Maybe it has something to do with the other information on the cards.
> ANA 3: Yeah, I know, but I don't know what to do different.

There was never a case in which symmetry was exhibited on the ship while a horizontal and vertically correct sort were exhibited on the unknown object. In only three cases (8%) symmetrical sorts were performed for both objects.

Significantly, of the eight participants performing symmetrical sorts before training, only four failed to resolve the conflict by post testing for the unknown object, although all had resolved it for the ship and produced correct sorts on that task.

Lead time relative to zero as it relates to "Phased time"

An interesting pattern of errors on all the scheduling probes suggests that, before understanding fully the concept of "phased time" participants understand the "backward time" idea first in terms of the parts' time relationship to the finished item, but not the parts' time relationships to other parts. Figure C. shows graphically a "fully phased" production schedule for 200 of a given item and all its parts while figure D. shows a representation of the partial concept, with "lead time" being assumed to pertain only to the part-whole relationship.

In pre-testing with the scheduling probe, 76% of all participants showed time strategies that are typical of experienced manufacturing workers in traditional plants and which did not in any way resemble an MRP phased Time strategy (i.e., "bottom up" or "now or recent past to later" as opposed to MRP's "future to present"). Four individuals (12%) showed phased time strategies in relationship to the part-whole relationship only. Two individuals (6%) showed complete understanding of MRP Phased Time in relation to both part/part and part/whole relationships. Two showed something in between; fully part-whole phased time and partial part-part phased time with some "bottom up" features. The first column of Table 14 summarizes these results.

An invariant sequence was found among these strategies within individuals. Participants who showed any strategy that indicated an understanding of part/part relationships also showed understanding of part/whole relationships. Of those showing part/whole time phasing in pre-testing (12%, column one, row two, in Table 14) 50% moved on to showing an understanding of both part/whole and partial part/part. The remaining 50% showed strategies indicating full part/whole part/part phased timing. Among all participants, there were no variations in the basic developmental sequence and no regressions. Only 14% failed to show any change with this concept. A chi square compared the distribution of invariant sequences from whole/part to part/part and whole/part among the participants with an expected even distribution among the same number of participants (with the same number showing no change) (p.<.00006).

Table 15 shows the patterns across probes and the percentages of participants that showed each pattern. This table breaks up the participants by job category; interestingly, Air Brake Maintainers were more likely to show their most advanced understanding on the Starship probe, -- which was significantly more complex, but which was something they had direct experience with -- while Analysts and supervisors were more likely to perform well with the abstract object -- which was a much simpler item. Because supervisors and analysts had such similar profiles when it came to this pattern, they were combined into one group for a statistical analysis. When supervisors are grouped with analysts, there were no significant differences on this concept (for this task) during pre-testing or overall during post-testing, but significant differences were found between the Supervisor/Analysts and ABM groups for the "abstract unknown" alone, $F(1, 30)=9$, $p<.006$.

Across all participants, however, a greater number of participants showed completely correct part/whole part/part phased timing when attempting the "abstract unknown" scheduling task as opposed to the starship task (41% as opposed to 18% of participants who attempted this task n= 30; see Table 14) and it remains to be explained why those who had a "fully phased" strategy on the "Abstract Unknown" had errors in their Starship schedules (see Table 15 for patterns). It may be that the greater number of parts in the starship (13 as opposed to the "abstract's" 3 parts) increased the chance for simple errors in calculation; if there were any errors in calculation at all, the strategy was coded as "part/whole partial part/part", and considered a stage "in between" part/whole-only and part/whole, full part/part. (See Method Chapter for complete description of recoding for part/part and part/whole). Therefore, a simple addition error could be coded as an incomplete understanding of part/part relationships.

Ignoring possible calculation errors (on the part of the participants) and reclassifying the "part/whole, partial part/part strategies as " part/whole, part/part", it was found that participants did better on the ship over all than on the abstract unknown; 74% showed "part/whole, full part/part" strategies on the ship while 48% achieved that on the abstract unknown.

The "scheduling" probe using the button top pen (the familiar but no-activity object) also proved difficult and elicited refusals (six out of 34 refused to try). Only 10% of those who attempted this task were able to manage the full part/whole part/part concept with the pen, and only 42% achieved the part/whole, partial part/part strategy or better (see Table 14).

Two to one vs. one to one.: An "item" concept with consequences for time and quantity

A concept that is related to the two above is the notion that, within an item, there can be a level change due to two or more parts combining to make another or due to a single part changing its form or state (such as being heat treated or cleaned). Figure E shows the difference between these two ideas. In MRP there is no functional difference. Developmentally however, the data suggest that participants seem to grasp the notion of many->one before one->one. This has consequences for their ability to calculate quantities accurately, understand item structures and set lead times properly. When this concept is misunderstood, rather than understanding that a part has changed, participants assume there are two parts to be obtained or manufactured. Sometimes these "two parts" are assumed to be processed simultaneously in time.

Data collected from the "scheduling" probes using the abstract object, the button top pen and the ship showed trends similar to those discussed above. These are summarized in Table 16. During pre-testing, only 28% (column one, rows 2 and 4 on table R.12) understood the notion of the many parts ->one, but even fewer grasped the notion of one ->one (6%).

Post test results again showed slightly stronger performance with the ship, and greater overall grasp of the many->one over the one->one relationship. For the abstract unknown, 11% showed strategies with a grasp of many->one only, and 75% grasped many ->one and one->one. For the ship, the results were 7% and 81%, respectively. Eighty two percent of participants showed knowledge of many->one for the pen (there were no one->one representations in the pen). Again, within participants, the trend of grasping many->one before one->one occurred in strict sequence and no reversals occurred although 14% failed to show any change at all (Chi Square $p<.0001$).

<u>**What do the correlations show?**</u>

Pearson correlations performed among demographic measures, measures of aggregate performance, and stage markers produced few reliable results. More noteworthy is the absence of significant correlations between, for example, prior computer and/or MRP experience and subsequent mastery of MRP concepts. Some relationships, however, are worth noting.

Only one demographic variable correlated significantly with performance. Those who had not graduated from high school showed a strong tendency to stick with traditional manufacturing strategies in post-testing. This finding surfaced as significant negative correlations with a number of the stage marker scores, as well as on aggregate MRP performance scores.

These negative correlations were the strongest with variables having to do with the ship. That is, while most participants performed to their maximum ability when solving problems with the ship, these participants did not experience an advantage when using the ship. It is difficult to interpret the meaning of these results; although significance was quite high ($p < .01$ in most cases) these results concerned relatively few participants, who were all around the same age and only a few years from retirement. They were also the least motivated during training. In other words, education may have less to do with it than other cohort based variables, such as impending retirement from the TA.

All educational level effects disappeared, however, when the participant had at least graduated from high school, whether it was a vocational high school or college preparatory school. No significant correlations were found even with computer education or experience, or with MRP education or experience.

Educational type exerted some influence. Vocational school attendance was negatively correlated with all MRP aggregate performance on any probe using an abstract unknown ("scheduling" A and "card sort" unknown), during post testing ($r = -.51$, $p < .01$) but no such trend was shown with the ship or the pen (which was familiar but for which there was no activity history). It seems that vocational school graduates, as a group, functioned best when the object was identifiable; when it was unknown, they had difficulty transferring MRP logic to the problem. The order of presentation also had no effect.

Those who had gone to college were more likely to sort the cards into a symmetrical pyramid during pre-testing, $r = .60$, $p < .01$. Transcripts of the dialogue taped during pretesting show that they were paying attention to the "level" information on the cards. Some talked about the "goes into" information (which would be needed for vertical accuracy) but they did not coordinate it with level information. Unlike other participants, they were also less likely to try and infer what the object was in order to sort the cards (although this finding was not significant).

<u>Discussion:</u>

It is clear from the post test results that two months after the "constructive" activity training workers performed on the probes in a manner similar to those workers in other sites who had managed to learn to use the system effectively (and who had been tested using the same probes). More importantly, workers exhibited these strategies spontaneously and appeared to have replaced old ways of doing the same problems with new approaches. For example, some participants reported that they realized they had done it differently before but could not replicate or remember their previous approach, a classic example of what Piaget called "depassement": structures at the higher stage completely reorganize structures at the lower stage, with the result that the older way of doing things is no longer available. This suggests that the "replacement" was effected by a reorganization of knowledge, and is further supported by other results. This point is addressed in more detail below.

The participants' performance on the floor supported these results. Even though the MRP implementation came to a crisis when upper management was replaced (and it seemed briefly that the system might be "pulled") shop floor personnel who had system access made use of the system to manage their own work areas, instructed management personnel in MRP and took upon themselves data entry and system upkeep.

The question remains - how did constructive activities effect this transformation?

It appears that "constructive" activities permit individuals to reorganize the implicit mental models which are driving the decision process. Both the data on overall strategies (both before and after the workshops) and the transition marker data support the claim that the participants were reorganzing old ways of thinking to create new ones. A description of what typically happens during the workshops will illustrate what is meant by constructive activities and suggest how they effect this process. As indicated, during the first morning of the workshops the teams of participants must "run" their factory in any way they choose as long as they meet the customers' orders on time, honor production lead times and pay the vendor on delivery for the materials and/or parts they purchase. Without exception, under this kind of pressure, all groups "default" to the strategies they normally use at work (as observed during the ethnographic phase of this study; see Appendix D for details). Comparing the performance in the workshops with job function indicates a strong correspondence between current work practices and decisions under pressure. For example, teams of mechanics almost always deliver a high quality product on time and thereby manage to stay financially above water by ensuring income. However, they do so often by buying finished assemblies (as opposed to raw materials) at great cost, by accelerating production (which has the real world equivalent in "overtime") and by overbuying all materials. Thus, they sacrifice profits. In contrast, teams of analysts and managers are often not successful at meeting customer orders or the poor quality of their work causes orders to be refused by the "customers". However, they are very hesitant to overspend; often they cannot meet orders because they have waited too long to decide to purchase the necessary materials. Importantly, individuals resort to these default strategies even when explicitly instructed to operate differently and when they are aware that the goal of the game is to make the most profit and buy the least material.

As indicated, during the workshops' first pause participants fill out forms, evaluate their net worth (calculating worth of material, WIP (work in process), cash and subtracting debt, damaged material and lost opportunity) and compare their production schedule and financial situation to an "MRP ideal" generated by a computer. During the discussions that follow the self evaluation, participants begin to reflect upon these default strategies and examine how a different approach might have accomplished their goals. It is only at this point that participants become aware of what assumptions have been guiding their decisions under pressure and with what results. We have come to call this the "deconstruction" phase and the beginning of "reorganization", both of which are necessary for eventually replacing an old strategy or way of thinking with a new one. During the MRP-oriented "constructive" activities that follow in next day and a half, participants continue a pattern of inventing a solution using their intuitive understanding of manufacturing, noticing its mismatch with their goals, reordering what they've done and comparing it again to their goals. At the end of this process, all participants arrive at the same solution but, importantly, the data suggest they have all gotten there via different paths and have begun the process through sometimes radically different entries.

It seems that constructive activities work -- and work for a wide variety of people -- because they permit a variety of entries to knowledge and they permit the individual's entry to be in terms of his or her existing way of thinking in that domain. In other words, rather than overlaying existing knowledge, constructive activities permit the reorganization of knowledge that occurs when learners are compelled to bring their current way of thinking to bear on the problem, notice its mismatch with desired outcomes, and make refinements in accordance with the tools they are discovering (in this case MRP).

To further illustrate the idea of entry point, let us return to some of differences found between the workers on specific tasks during post-testing. First, although there were no significant differences between the ABMs and Analysts on overall performance, differences in their patterns of response on specific tasks indicate they were "coming to" the same notions through different means. For example, on the "scheduling" tasks, almost all of the task specific variance between groups was due to performance on the "abstract unknown" probe. Although this task was much simpler than the same probe using the starship or pen (3 parts as opposed to 13 parts with various lead times) mechanics (ABMs) exhibited the most sophisticated strategies with the more complex, but identifiable objects. The paradox of the more complex (but more concrete) being simpler for one class of participants suggests interesting possibilities. It seems as though this group was not oriented to approaching problem solving when the context was presented abstractly although they were capable of thinking abstractly and symbolically about contexted objects. Conversely, the analysts were able to take better advantage of the simplicity of the "abstract unknown" and were more likely to make calculation errors on the starship task. This result is particularly interesting given that abstract problem solving is sometimes invoked as more sophisticated than "concrete" or contexted problem solving. Only a third round of interviews -- conducted months later -- could shed light on the meaning of this difference; if the two groups are coming to the same understanding through different paths they should perform in an increasingly more similar fashion on all tasks as mastery develops.

The mechanics' ability to operate with the complex but concrete makes sense given their jobs. They are required to work with highly complicated assemblies (containing hundreds of components) with many small, but essential parts. In order to perform well on the job they must pay attention to small details, and to the potentially dangerous impact of small assembly errors. It may be that the requirements of their jobs have oriented them to grasp general relationships or concepts through the specifics, while at the same time being more able to handle a large amount of detail in parallel. The differences between the ABMs and the Analysts on specific tasks offer support to the more general notion that job-specific ways of thinking may influence ways of learning -- in that they influence the what-is-to-be-reorganized -- and that activities or learning situations that permit multiple ways to attend to information and concepts may erase normally observed group differences in overall ability to learn.

More support for the idea that constructive activities effect reorganization, and hence eventually, replacement is provided by the data on the effects of the "procedural" activities. Despite considerable practice with MRP's methods of calculating virtual quantities, all but two (6% on table 4) participants defaulted to their previous methods of calculating quantities during the post probe interviews. In other words, no "replacement" took place for most when it came to quantity strategies. Clearly, hearing concepts explained and even practicing formulas for hours did not engender real change or in depth understanding.

We are still left with the unanswered question of mechanism. The fact that constructive activities permit the construction of knowledge from multiple entry points is, in itself, not compelling unless we consider why. If we consider constructive activities in view of the reported "error patterns" (which tended to be orderly and sequential) more is revealed. Re-examining the nature of the errors shows that, in general, participants were both "re-creating" MRP principles for themselves, and doing so by appropriating the surface features first, and getting the more subtle aspects later. This is shown most clearly in participants' tendency toward symmetrical sorting. Symmetrical sorts could be said to represent a kind of simplified reconstruction of the MRP notion of hierarchy. Although they have no basis in MRP systems, they may have some basis in most adults' experience with superordinate and subordinate category systems. In other words, it seems that adult learners learn by constructing and re-creating the domain for themselves in any case, and assimilate structures (in the Piagetian sense) from other learning in order to do so, focussing first on surface or gross similarities in an effort to bring some existing heuristic to bear on the new situation. Constructive activities seem to take advantage of this tendency. Rather than attempting to push old knowledge out of the way, constructive activities may permit it to be used as fodder for developing a new way of thinking about the same things. This may explain, in part, why there was replacement rather than addition for some of the participants who tried to recall their previous way of doing things. If the reorganization takes place at the level of what is spontaneously and intuitively drawn upon, it may be that the original model of things is so changed it is lost in its original form.

On the other hand, the scant data from the participants who showed a more "integrated" approach suggest that, with resuming real world problem solving, the "old" model may reassert itself somewhat, but in a form that incorporates MRP ways of thinking. The reader will recall that some workers who continued to engage in "constructive" activities on the floor showed an "integrated" set of strategies during post-testing. In addition, one supervisor (SUP3) who showed a marked MRP bias during pre-testing showed an integrated approach during post-testing. Together, these results suggest that after the workshops workers may resume their duties with a marked "MRP bias", but with experience, their thinking becomes more integrated. The complete absence of an integrated approach among analysts (who have no hands-on manufacturing experience after the workshops) also supports this notion, but the data from this study are too scant to draw any definite conclusions.

Although this dissertation presents only a small portion of a huge corpus of data -- with much potential for further analyses -- it makes a compelling case for rethinking education for adults who already have considerable skills. These results suggest that the "default" mode or intuitive understanding that is developed with experience may act as both an impediment and bridge to learning new technologies in one's domain of expertise. Constructive activity based learning may offer a way to make an impediment into a bridge without sacrificing current experience and expertise.

Table 1.

Pre-testing Performance probes shown with the MRP core concepts targeted.

PROBE	CORE CONCEPTS: MRP	CORECONCEPTS:Manufacturing
Scheduling Item "A"	Phased time* Hierarchical items Quantity per	finished good/part Assembly process Horizon/ Capacity
Card sort (carton of tacks)	Item structure*	finished good/part assembly process
Tree	Virtual Quantity* Quantity per	Finished goods/parts Min/Max On Hand quantity

* Targeted MRP concept

Table 2.

Post-test Performance probes shown with the MRP core concepts targeted.

PROBE	CORE CONCEPTS: MRP	CORE CONCEPTS: Manufacturing
Scheduling Item "A"	Phased time* Hierarchical items Quantity (quantity per)	finished good/part assembly process Horizon/capacity
Scheduling Model 3 Starship	Phased time* Hierarchical items Quantity (quantity per)	(See above)
Scheduling top button Pen (familiar, no activity object)	Phased time* Hierarchical items Quantity (quantity per)	(See above)
Card sort (carton of tacks)	Hierarchical Item*	Finished Good/part Assembly process
Card sort (Starship)	Hierarchical Item*	(See above)
Tree	Virtual Quantity* Quantity per	Finished goods/parts Min/Max On Hand quantity

* Targeted MRP concept

Table 3. Strategies Associated with MRP and Traditional Manufacturing approaches, categorized by related MRP principle.

MRP Strategies

Time:
1. Schedules backward from future date to closer future date
2. Begins with end item when scheduling end item and parts
3. Schedules parts beginning with level one items
4. Schedules levels sequentially (1, 2, 3, etc.)

Item:
1. Structures end items beginning with end item
2. Structures levels according to how object is made (things needed at the same time on the same level)
3. Structure is redundant, with the whole item re-represented at least on level one.
4. Does not re-represent items that do not represent a re-stocked part.

Quantity:
1. Quantity is calculated as "quantity per" parent item.
2. "on hand" is Physical count - allocated + scheduled receipt
3. Upper level components are used before lower level requirements are calculated.
4. When lot sizes are not specified, purchasing and manufacturing are calculated as "lot for lot" or one made to one needed.
5. Demand/requirements are calculated before work is planned.

Traditional Manufacturing Strategies

Time:
1. Schedules begins now with purchasing/work spread out evenly until due date (e.g., horizon method).
2. Begins scheduling with raw materials or "ingredients".
3. Continues scheduling by moving "bottom up" from raw materials to end items or may not schedule subassemblies separately from end items (e.g., time needed to complete end item may be an aggregate of all assembly times for sub-components of the item).

Item:
1. End item is comprised of its part; End item alone may not be represented
2. structure (if any) looks like a routing with "what's to be done" relationships rather than "when to be done".
3. Structure is non-redundant and "cluster-like".

Quantity:
1. Quantity is calculated as "quantity per" end item.
2. "on hand" is Physical count
3. Requirements are calculated at each level using an "aggregate" method (e.g., min/max)
4. Ordering is done in lots.
5. Reordering is based on replenishment principles, and not demand driven.

Table 4.
Aggregate scores on scheduling probes, indicating overall MRP strategies. Post-workshop averages do not include subjects who refused to complete one or more of the scheduling tasks.

Subject	Pre-test	Post	ship	button pen	Average Post-test
SUP1	.25	–	.83	.66	.75
SUP2	.00	1.00	.74*	.08	.58
SUP3	1.00	.66*	.63*	.70	.66
SUP4	1.00	.58	.66	1.00	.75

Pre-workshop average for supervisors: .56
Post-workshop Average for supervisors: .69

Subject	Pre-test	Post	ship	button pen	Average Post-test
ABM1	.35	1.00	1.00	—	1.00
ABM2	.00	1.00	.75	.58	.78
ABM3	.08	.33	.66	.16	.38
ABM4	.41	—	—	—	.00
ABM5	.16	.16	.54*	.66	.45
ABM6	.00	.13	.63*	.66	.47
ABM7	.08	.33*	1.00*	1.00	.78
ABM8	.16	1.00	.66	.58	.75
ABM9	.08	1.00	1.00	.66	.89
ABM10	.08	—	.87	—	.87
ABM11	.33	.58	.83	.75	.72
ABM12	.00	.58	.58	.64	.60
ABM13	.12	.66	.66	1.00	.77
ABM14	.12	.58	.70	.63	.64
ABM15	.08	—	—	—	
ABM16	.08	.08	.08	.00	.05
ABM17	.08	.41	.41	.36	.39
ABM18	.16	.63	.66	.55	.61

Pre-workshop average for ABMs: .13*
Post workshop Average for ABMs: .67

Subject	Pre-test	Post	ship	button pen	Average Post-test
ANAL1	.08	1.00	.83	.75	.86
ANAL2	.16	—	.41	.20	.31
ANAL3	.58	1.00	.83	—	.92
ANAL4	.16	.37	—	—	.37
ANAL5	1.00	1.00	.83	.63	.82
ANAL6	.25	1.00	.75	1.00	.92
ANAL7	.66	.66	1.00	.66	.77
ANAL8	.58	1.00	1.00	1.00	1.00
ANALY9	.08	1.00	.66	.66	.77
ANALY10	—	.58	.66	.66	.63
ANALY11	.66	1.00	1.00	.58	.86

Pre-workshop average for analysts: .42*
Post workshop Average for analysts: .75

ANOVA comparing Analysts' and ABMs' pre-workshop averages across tasks, $F(1, 28) = 11.3$ $p < .002$.

Table 5.
Aggregate scores on scheduling probes, indicating overall Manufacturing strategies. Post workshop averages do not include subjects who refused to complete one or more of the post workshop scheduling tasks.

Subject	Pre-test	Post	ship	pen	Average Post-test
SUP1	1.00	--	0.00	0.00	.00
SUP2	.80	0.00	.70	1.00	.85
SUP3	0.00	.90	.80	.80	.83
SUP4	.30	0.00	0.00	0.00	.00
	Pre-workshops average for supervisors: .53				
	Post-workshop average for supervisors: .42				
ABM1	.80	.00	.00	--	.00
ABM2	.80	.00	0.00	0.00	.00
ABM3	1.00	1.00	1.00	1.00	1.00
ABM4	.80	--	1.00	--	1.00
ABM5	1.00	1.00	1.00	.54	.85
ABM6	.80	1.00	1.00	1.00	1.00
ABM7	.80	.80	.40	.40	.53
ABM8	1.00	0.00	0.00	0.00	.00
ABM9	1.00	0.00	0.00	0.00	.00
ABM10	.80	—	1.00	—	1.00
ABM11	.60	0.00	0.00	0.00	.00
ABM12	.60	0.00	0.00	0.00	.00
ABM13	.80	0.00	0.00	0.00	.00
ABM14	.80	0.00	0.00	0.00	.00
ABM15	.60	—	—	—	
ABM16	.60	.08	.08	.08	.08
ABM17	.60	0.00	0.00	0.00	.00
ABM18	1.00	.30	0.00	0.00	.10
	Pre-workshop average for ABMs: .80				
	Post workshop average for ABMs: .25				
ANAL1	1.00	0.00	0.00	0.00	.00
ANAL2	1.00	--	1.00	1.00	1.00
ANAL3	0.00	0.00	0.00	—	.00
ANAL4	1.00	.60	.50	.50	.53
ANAL5	0.00	0.00	0.00	0.00	.00
ANAL6	1.00	0.00	0.00	0.00	.00
ANAL7	.80	0.00	0.00	0.00	.00
ANAL8	0.00	0.00	0.00	0.00	.00
ANAL9	1.00	0.00	0.00	0.00	.00
ANAL10	--	0.00	0.00	0.00	.00
ANAL11	0.00	—	0.00	0.00	.00
	Pre-workshop average for Analysts: .52				
	Post workshop average for Analysts: .06				

ANOVA comparing Analysts' and ABMs' pre-workshop averages for all tasks ($F(1, 30) = 11.31$, $p < .0001$).

Table 6.
Average scores between domains for each occupational group, showing replacement of Traditional Manufacturing Strategies with MRP strategies

Pre-workshop

Post-workshop

	Manufacturing	MRP	Manufacturing	MRP
SUPs	.52	.56	.42	.69
ABMS	.80	.13	.25	.67
Analysts	.52	.42	.06	.75

Table 7. Aggregate scores for MRP strategies on card sorts

Subject	pre-sort "abstract unknown"	post-sort "abstract unknown"***	post-sort starship	average post-score
SUP1	.00	.75	.75	.75
SUP2**	.25	.75	.75*	.75
SUP3**	.75*	1.00*	1.00*	1.00
SUP4	.25	.75	1.00	.88
Average among supervisors Pre: 31.25; Post 84.5 ***				
ABM1	.00	.75*	.75*	.75
ABM2	.00	.50	1.00	.75
ABM3	.00	.38	1.00	.69
ABM4	.00	.50	.75	.00
ABM5	.00	.50	.63	.57
ABM6	.00	.00	.00	.00
ABM7**	.50	.50	.75*	.66
ABM8**	1.00	1.00*	1.00*	1.00
ABM9	.63*	1.00*	1.00	1.00
ABM10	.25	.25	—	—
ABM11	.50	.50	1.00	.75
ABM12	.25	.75*	1.00	.88
ABM13	.63	1.00*	1.00	1.00
ABM14	.00	.75	—	.75
ABM15	.00	.25	.63	.44
ABM16	.00	.—	.25	.25
ABM17	.00	.75*	.50	.66
ABM18	.50	.75*	.75*	.75
Average among ABMs Pre: 23.6 Post 64.1				
ANAL1	.50	1.00	1.00	1.00
ANAL2	.00	.75	1.00	.88
ANAL3	1.00	1.00	1.00	1.00
ANAL4	.50	.75	.50	.63
ANAL5	.75	.75	1.00*	.88
ANAL6	.00	.75	1.00	.88
ANAL7	1.00	1.00	1.00	1.00
ANAL8	1.00	.75	1.00	.88
ANAL9	.00	.75	1.00	.88
ANAL10	--	.75	1.00	.88
ANAL11	.75	—	1.00	1.00
ANAL12	.25	.75	.75	.75
Average among Analysts Pre: 52.2 Post: .89				

* Indicates "integated" MRP and manufacturing strategy
** Indicates this subject's "integrated" MRP and manufacturing strategy co-occurred with classic MRP sort*** ANOVA comparing all groups on this task only, $F(2, 30) = 5.03$, $p < .01$

Table 8.
Aggregate scores for traditional manufacturing on card sorts

Subject	pre-sort "abstract unknown"	post-sort "abstract unknown"**	post-sort starship	average post-score
SUP1	.50	.33	.33	.33
SUP2	.33	.00	.66*	.33
SUP3	.66*	.50*	.50*	.50
SUP4	.00	.00	.00	.00
	Average among supervisors Pre: 37.25; Post 29.0 ***			
ABM1	.66	.41*	.33*	.37
ABM2	.66	.00	.00	0.00
ABM3	.50	.41	.00	.21
ABM4	.33	.00	.00	.00--
ABM5	.66	.00	.00	.00
ABM6	.66	.66	.00	.33
ABM7	.50	.50*	.50*	.50
ABM8	.00	.50*	.00*	.25
ABM9	.50	.50*	1.00	.75
ABM10	.50	.50	—	.50
ABM11	.66	.50	.00	.25
ABM12	.50	.25*	.00	.13
ABM13	.41	.33*	.00	.17
ABM14	.75	.00	—	.00
ABM15	.50	.66	.33	.50
ABM16	.50	.--	.--	.--
ABM17	.58	.41*	.58	.50
ABM18	.00	.41*	.75*	.58
	Average among ABMs pre: 49.27 post: 30.2			
ANAL1	.00	.00	.16	.08
ANAL2	.50	.00	.00	.00
ANAL3	.00	.00	.00	.00
ANAL4	.66	.00	.00	.00
ANAL5	.50	.00	.50*	.25
ANAL6	.66	.50	.00	.25
ANAL7	.00	.00	.00	.00
ANAL8	.00	.00	.66*	.33
ANAL9	.50	.00	.00	.00
ANAL10	--	.00	.00	.00
ANAL11	.50	—	.00	.00
ANAL12	.16	.00	.41*	.21
	Average among Analysts pre: 31.6 post: 9.45			

* Indicates "integated" MRP and manufacturing strategy
** ANOVA comparing all groups on this task only, $F(2, 28) = 8.41$, $p < .001$)
*** ANOVA comparing all groups on average for all tasks $F(2, 28) = 4$, $p < .02$)

Table 9.
Differences in Overall performance on three core concepts. Data from "Tree", "Scheduling" and "card Sort" probes. Percentages represent proportion of subjects with strategies showing full grasp of the principle involved.

(Underlying Principle)	Relative Quantity	Phased Time	Hierarchical Item
Pre-test	*0%	** 12%	**** 15%
Post-test	*6%	** 48%	**** 22%
Post-test "Starship" tasks	*NA	*** 74%	***** 79%

* Tree Virtual Quanity probe.
** Phased time analysis from"scheduling abstract unknown" probe
*** Phased time analysis from "scheduling starship" probe
**** Hierarchical item analysis from "unknown object card sort" probe
***** Hierarchical item analysis from from "starship card sort" probe

Table 10.
Answers to "Tree" Quantity Question. Percentages show frequency of each possible answer among all subjects.

	Pre	Post
Adds all "180,000"*	89% (31)	47% (16)
grasps partial redundancy with quantities "140,000"**	6% (2)	12% (4)
Grasps full redundancy "120,000"***	6% (2)	35% (12)
Can give a variety of correct virtual quantities****	0%	6% (2)
N =	35	34

* Indicates no concept of how MRP calculates quantities and indicates a typical tradition manufacturing strategy.

** Indicates that the subject realizes that <u>some</u> of the parts on the tree are actually subassemblies of other parts and need not be counted twice.

*** Indicates that the subject realizes every part that undergoes some change before the final assembly need not be counted twice, but being able to give <u>only</u> this answer indicates that the individual does not yet realize that the "what" that gets counted can be relative and a variety of answers are possible.

**** Indicates a fully flexible notion of virtual quantity.

Table 11.

Patterns of mastery among the three MRP principles exhibited by subjects across performance probes.

Full mastery of Core concepts as indicated on strategies. Percentages refer to subjects

	Pretests*	Post Workshop**	Post Workshop (starship tasks)***
Q only	0%	0%	0%
T only	0%	0%	0%
I only	0%	5%	0%
QI only	0%	0%	0%
TI only	0%	15%	16%
QTI	0%	6%	7%

Partial Mastery of Core concepts

	Pretests*	Post Workshop**	Post Workshop (starship tasks)***
Q only	0%	0%	0%
T only	0%	0%	0%
I only	0%	0%	0%
QT only	0%	0%	0%
QI only	0%	0%	0%
TI only	4%	10%	34%
QTI	5%	45%	35%

* Tasks used: Pre-probe tree (quantity), card sort (item), scheduling abstract unknown (Time and item)

** Tasks used: Post-probe tree (quantity), card sort (item), scheduling abstract unknown (Time and item)

*** Tasks used: Post-probe tree (quantity), starship card sort (item), starship scheduling (time and item).

Q = Virtual Quanity
T = Phased Time
I = Hierarchical Item

Table 12.

Overall Percentages for Symmetry/Asymmetry and "non-level" performance on "Card Sort" probes for all subjects, all card sort tasks.

Type of Answer	Pretest card sort "unknown" object	Post test card sort "unknown" object	Ship card sort "Model 3"
No level understanding*	61%	16%	9%
Symmetry (horizontal level) **	24%	62%	12%
Asymmetry Vert and Horizontal***	15%	22%	79%
N =	34	32	34

* The subject produced a sort with no MRP-like item structure represented at all, e.g., usually an assembly sequence was constructed.

** The subject sorted cards by level only <u>and</u> formed a symmetrical pyramid with the cards.

*** The subject arranged cards in a classic MRP item structure, coordinating "level" information with "goes into information between all cards.

Table 13. Observed Sorting patterns among all subjects showing invariant sequence from Symmetry to Asymmetry on the three "Card Sort" probes

Percentage of s's		Pretest card sort	Post test card sort	Ship card sort
%	N			
8.5%	(3)	0	0	0
8.5%	(3)	0	1	1
40%	(14)	0	1	2
0%	(0)	0	2	2
11%	(4)	2	2	2
8.5%	(3)	1	2	2
8.5%	(3)	1	1	2
3%	(1)	0	0	2
3%	(1)	1	--	2
3%	(1)	0	--	1
3%	(1)	0	0	--
3%	(1)	2	1	2*

* indicates only case of non-sequential progression
– indicates refusal to attempt task.
Invariant sequence of patterns: Chi square (<u>p</u> <00001)

0 The subject produced a sort with no MRP-like item structure represented at all, e.g., usually an assembly sequence was constructed.

1 The subject sorted cards by level only <u>and</u> formed a symmetrical pyramid with the cards.

2 The subject arranged cards in a classic MRP item structure, coordinating "level" information with "goes into information between all cards.

Table 14.
Part/whole vs Part/part coordination; Data from "scheduling" probes

	Pre probe "A"	Post probe "A"	Post probe "ship"	Post "pen"
Does not grasp any relationship between parts or parts and wholes	76%	31%	18%	14%
grasps only part/whole	12%	20%	8%	43%
Grasps part/whole & partial part/part	6%	8%	56%	32%
Grasps Full part/whole & part/part	6%	41%	18%	11%
N =	33	29	34	28

Table 15.

Part/whole vs Part/part coordination. Patterns observed among all subjects' "scheduling" probes. Completed protocols only.

	Pre Probe "A"	Post probe "A"	Post probe "ship"	Post "pen"
Supervisors/Analysts				
	0	3	2	0
	0	3	2	0
	0	3	2	2
	0	3	2	2
	0	3	2	1
	0	3	2	3
	3	3	2	2
	1	3	2	–
	0	1	3	1
	2	3	3	2
	0	0	2	2
	0	3	1	1
Air Brake Maintainers				
	0	3	3	–
	0	3	2	1
	0	0	2	1
	0	0	2	1
	0	0	2	1
	0	0	3	2
	1	3	3	2
	0	1	2	2
	0	1	2	1
	0	1	2	3
	0	2	2	2
	0	0	1	0
	1	2	2	1

0=NR: Strategy does not show any relationship between parts and wholes or parts and parts
1=PW: Strategy shows only part/whole relationship
2=PWp: Strategy shows both Part/whole, and partial part/part relationships
3=PWP: Strategy shows both Part/whole and full Part/part relationships.

Table 16.
Many->one vs. One->one coordination on all subjects' "scheduling" probes.

Strategy Type	Pre	Post	post ship	post pen
Strategy does not represent either many->one or one->one relationships	72%	14%	12%	18%
Strategy shows only many->one	22%	11%	7%	82%**
Strategy shows only one ->one*	0%	0%	0%	0%
Strategy shows both many->one & one-> one	6%	75%	81%	NA**
N=	32	29	34	28

* No subjects grasped one->one without also grasping many ->one

** The Pen had no one->one relationships

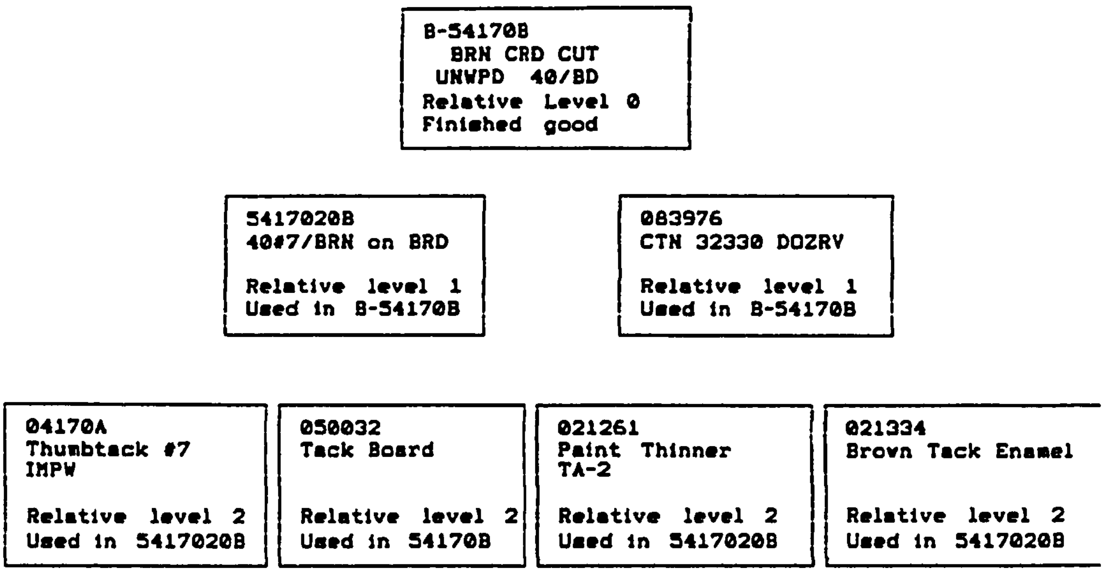


Figure A.
Symmetrical Sort

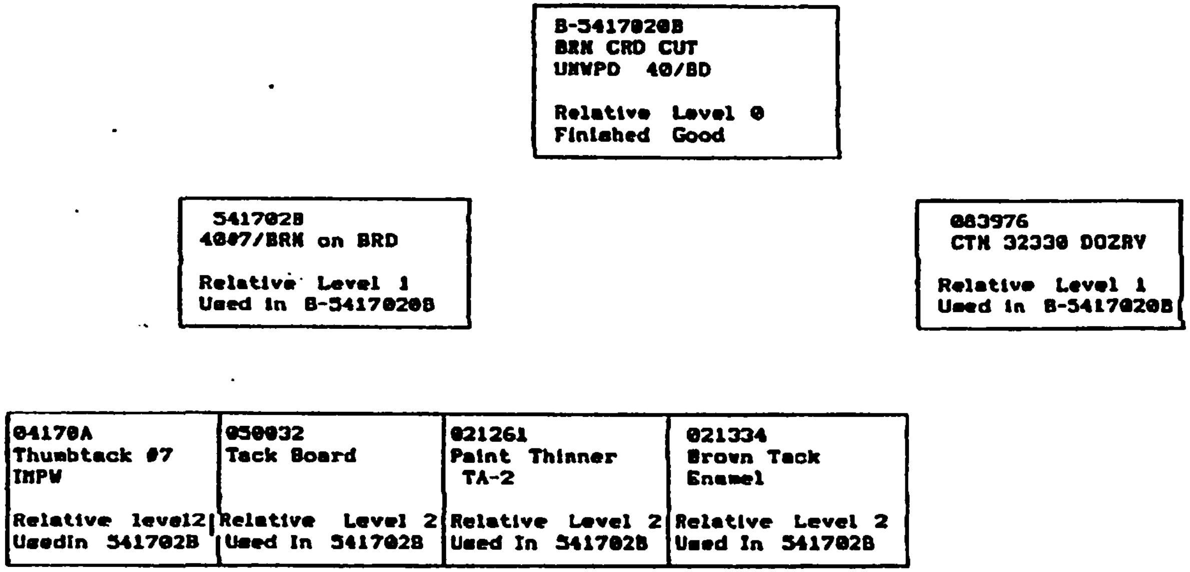
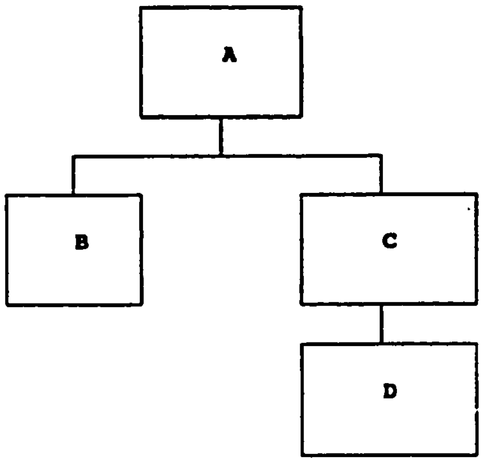


Figure 8. MRP Asymmetrical Sort



Item Number	Description	Relative Level	Lead Time	Quantity Per
A	A	0	2 months	
B	B	1	1 months	1
C	C	1	1 months	1
D	D	2	2 months	1

Schedule Item A and all of its components so that an order for 200 of the finished good A can be shipped in August.

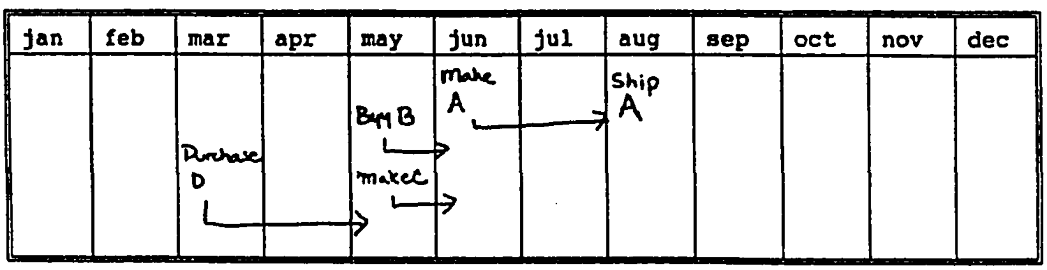
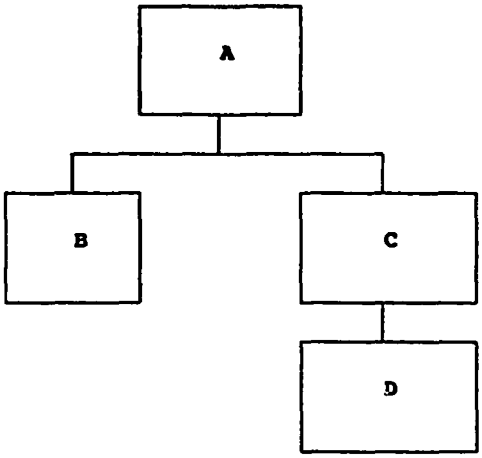


Figure C.
Fully Phased Schedule

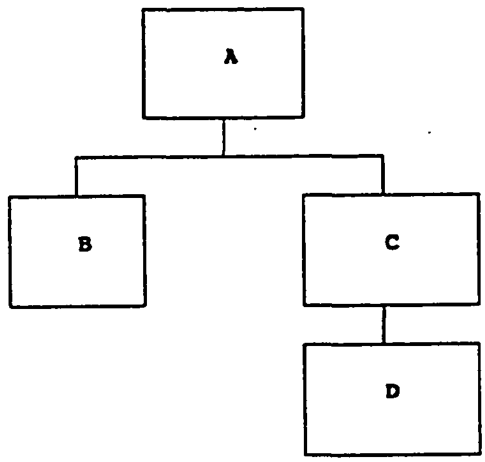


Item Number	Description	Relative Level	Lead Time	Quantity Per
A	A	0	2 months	
B	B	1	1 months	1
C	C	1	1 months	1
D	D	2	2 months	1

Schedule Item A and all of its components so that an order for 200 of the finished good A can be shipped in August.

jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
			Buy D →	Buy B → make C →	Make A →		Ship A				

Figure D.
Partially Phased Schedule



B and C are combined to make A. This represents the many->one relationship in MRP. When B and C are combined, they become a third item, which resides on another level.

D is transformed into C after some kind of process. This represents the one ->one relationship in MRP. When D undergoes some kind of process, it becomes (for MRP) a completely different item on another level.

Figure E.
Illustration of the Many-> One
and One-> One part-part relationships

Appendix A: Probe Materials

The questions that follow concern information that we are seeking for our research on work and learning in the workplace. If for any reason, you do not want to answer a particular question, simply go on to the next one. All of our research will be displayed in general findings, and confidentiality to persons involved is guaranteed.

Name:______________________________

Current Job Title:____________________

Department:_________________________

Age group: under 25__________
26-35__________
36-45__________
46-55__________
over 55__________

What is your country of origin?______________________________

What languages do you speak fluently?______________________________

What is your educational background? Please fill in the chart below, indicating what levels of formal education you attained, what you studied, when, and where:

	Have you attended courses at:	Did you complete a degree?	What subject area did you study?	What years did you attend?	Where did you attend?
Highschool	yes ___ no ___	yes ___ no ___			
Vocational or Technical	yes ___ no ___	yes ___ no ___			
College	yes ___ no ___	yes ___ no ___			

Have you taken any courses or workshops that are specifically related to the work you do?

yes ___ no ___

What were they and when did you take them? Please fill out the chart below:

What was the title of the workshop or course?	How long did it last? A week? More?	Did it result in any kind of certification? What?	Did your employer pay for the course?	When did you take it?

How many years have you worked in electronics?__________ mechanics?______________

Please list the jobs you had before you came to the Transit Authority:

Job Title	Type of Company	For how long, and when?	Briefly describe what you did

When did you start working at the Transit Authority?________________

What jobs have you held in the Transit Authority? Please fill out the chart below:

Job Title	Department	For how long and when?	Briefly describe what you did

Do you currently use or access any computer system on your job? yes___ no___

If yes, which ones? ____

If yes, do you access them to gather information________

to check information________

to input information________

Have you had any on-the-job training about the computers in your workplace?

yes ___ no ___

Have you attended any courses or workshops about the computers in your workplace?

yes ___ no ___

Please list all computer-oriented courses or on the job training, and note when:

____

____

____

____

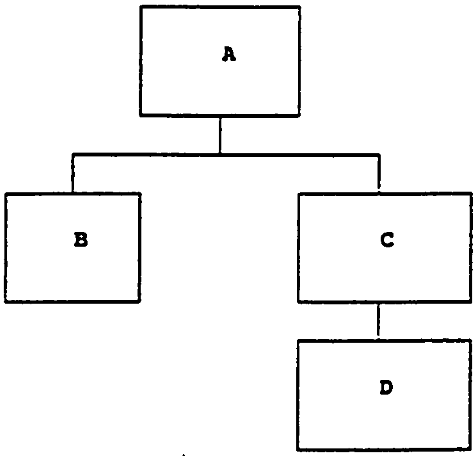
Have you ever heard of MRP? yes___ no___

If yes, have you ever worked with MRP? yes___ no___

19. Card sort

After informant has sorted the cards, put the end item card on the table and indicate that some people sort with this card at the "top" with others arranged below. Ask how the informant would accomplish this with some logical consistency.

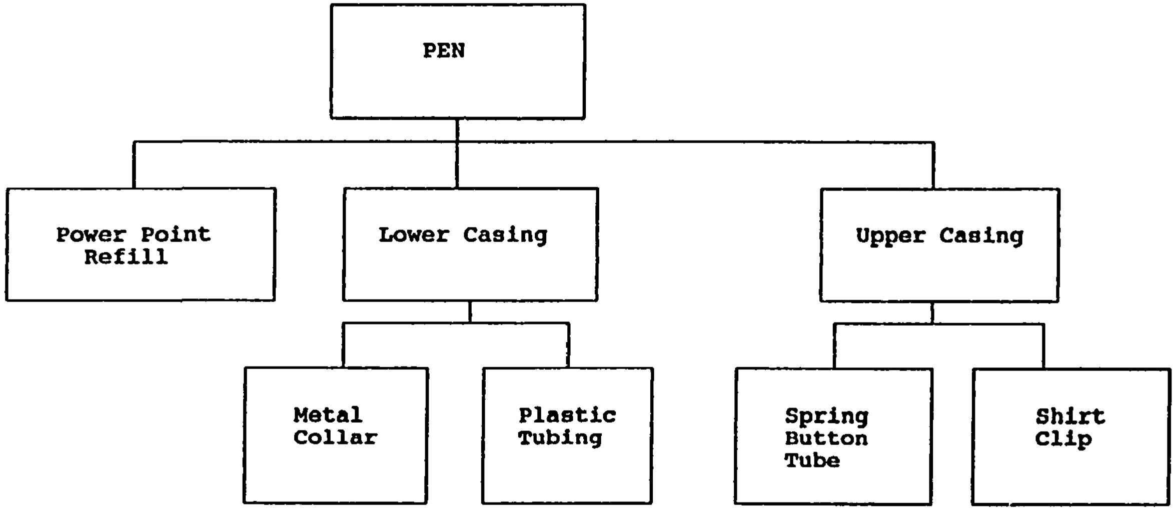
(After informant arranges cards, arrange them yourself with the end item at the top, and the "used in" cards placed properly on proper levels). Ask the informant "does this make any sens to you?"



Item Number	Description	Relative Level	Lead Time	Quantity Per
A	A	0	2 months	
B	B	1	1 months	1
C	C	1	1 months	1
D	D	2	2 months	1

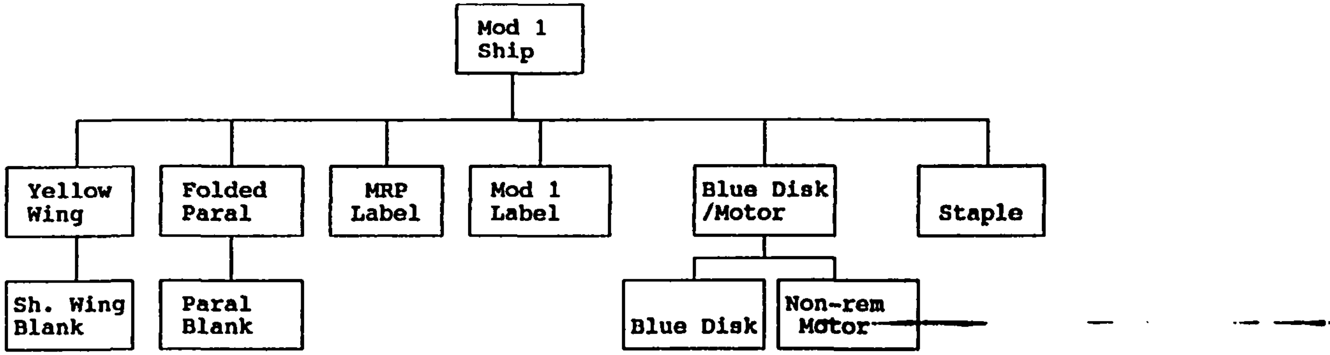
Schedule Item A and all of its components so that an order for 200 of the finished good A can be shipped in August.

jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec



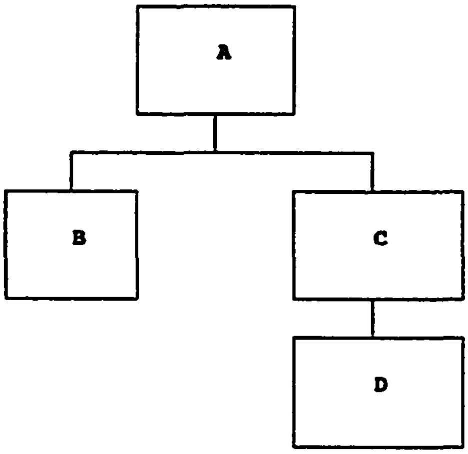
Item #	Description	Relative Level	Lead Time	Quantity Per
8529	Pen	0	1 day	
8503	Power Point Refill	1	5 days	1
8504	Lower Casing	1	1 day	1
7920	Plastic Tubing	2	2 days	1
7930	Metal Collar	2	1 day	1
8505	Upper Casing	1	1 day	1
7935	Spring Button Tube	2	2 days	1
6849	Shirt Clip	2	3 days	1

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9



Item #	Description	Relative Level	Lead Time	Quantity Per
000.10	Starship, Model 1	0	1 week	
004.10	Wing, Short Yellow	1	1 week	2
009.22	Wing, Short Blank	2	1 week	1
002.10	Folded Parallelogram	1	1 week	1
009.21	Parallelogram Blank	1	1 week	1
009.04	MRP Game Label	1	2 weeks	1
009.01	Label: Model 1	1	2 weeks	1
001.10	Blue Disk/Motor Ass'y	1	1 week	1
003.10	Blue Disk	2	1 week	1
003.60	Motor, Non-Remov	2	3 weeks	2
009.05	Staples	1	1 week	2

Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8



Item Number	Description	Relative Level	Lead Time	Quantity Per
A	A	0	2 months	
B	B	1	1 months	1
C	C	1	1 months	1
D	D	2	2 months	1

Schedule Item A and all of its components so that an order for 200 of the finished good A can be shipped in August.

jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec

Appendix B
Coding Manual, Coding Forms,
Sample of subject's coded performance

Coding Instructions:
Coding Form: Card Sort for "unknown" object and Card sort for the "ship".

MRP Orientation: Put a "1" if the subject's overall strategy or stated goal is to create an item structure that MRP could use.

Indicators: 1. Separates the "finished" good card from the rest, and/or places it at the top of the sort.
2. Constructs anything hierarchical.

Indicators for a "0"

3. constructs a linear sequence.
4. makes clusters of similar parts
5. uses the stock numbers to order cards.

Top down:

"1" if the subject sorts cards in a top down manner, beginning with the finished good.

By Levels:

"1" if the subject sorts the cards using the "level" information on each card, putting all cards of the same level together, in a row, column, pile or cluster.

Goes Into:

"1" if the suject sorts the cards using the "goes into" information on each card, putting all cards going into the same thing together, or by putting the cards with the other cards that they "go into"

Symmetrical

"1" if the subject makes a symmetrical pyramid structure, using the level information, without regard to the "goes into" information.

Total:

Add up all "1's". For the converted proportion, divide total by 5.

Manufacturing Orientation
"1" if the subject sorts with an overall manufacturing orientation

Indicators for a "1"

1. constructs a linear sequence.
2. makes clusters of similar parts
3. uses the stock numbers to order cards.

Horizon

"1" if the subject talks about or tries to build a time factor into the sort. For example, putting a lot of space between two cards and saying that the space represents a long time between processes.

Linear

"1" if the subject places the cards in a left to right linear sequence, either based on ordering by stock number, by inferred process, imagined assembly line, or by an imagined purchasing sequences.

Infers process

"1" if the subject talks about or tries to represent an imagined manufacturing process and sorts the cards according to this scheme. <u>The process must not consider material requirements planning.</u>

Assy Clusters

"1" if the subject sorts the cards according to imagined assemblies, of what gets combined with what during an imagined assembly sequence.

Total:

Add up all "1's". For the converted proportion, divide total by 5.

Information used/mentioned

Indicate any information the subject indicates he/she is using to make judgements while sorting

Does the S. make the object concrete?

"1" if the S. insists on knowing what the item is, or indicates that the sort can't be done unless he/she knows what the item is. Also if the S. invents an item and parts that the card might represent.

Coding Instructions:
Scheduling Questions for "unknown" abstract object, Button Top Pen and Ship Model 1.

Manufacturing Orientation
"1" if the subject sorts with an overall manufacturing orientation

Indicators for a "1"

1. constructs a linear sequence of ordering, building and shipping
2. makes clusters of similar parts when scheduling purchasing
3. Spreads work out to fill whole schedule

Capacity

"1" if the subject talks about or tries to build a schedule that evening spreads the work done over several months. Usually this is indicated by the subject dividing 200 by the desired number of months and scheduling a fixed amount each month.

Bottom up?

"1" is subjects begins his schedule early in the calendar and moves left to right, beginning with "raw" materials.

Begins in Jan

"1" if the subject begins the schedule in January.

Infers Linear Process

"1" if the subject infers or invents a production or assembly process and schedules the processes, left to right.

Total:

Add up all "1's". For the converted proportion, divide total by 5.

MRP Orientation: Put a "1" if the subject's overall strategy or stated goal is to replicate an MRP based strategy (even if unsuccessful)

Indicators: 1. Marks the "due date" and speculates how to meet it in time.

2. Considers the due dates of sub assemblies, given the due date of the finished good.

Indicators for a "0"

3. constructs a linear sequence.
4. makes clusters of similar parts
5. makes capacity a priority.

Schedules back from the End Item:

"1" if the subject begins with the due date and schedules backward, beginning with the zero level, going next to level one items, then to level two, and so on. If subject writes in the lower levels first, it is still considered a "backward" strategy if talk or other behavior indicate that he is counting back from the due date to establish which boxes to write in.

All Lead Times accurate:

Code as "6" only if all lead times are absolutely accurate. Skip right to "Appropriately gets redundancy"

Some Lead time concept:

"1" if the suject indicates through talk or other behavior that he is thinking about or paying attention to lead time as the times one needs to consider for planning both finished goods and sub-assemblies.

Appropriate Lead Time but miscalculated.

"1" if the subject attempts appropriate lead time calucations for all items, in relationship to the appropriate "parent", but has a slight miscaculation (e.g., counts the boxes incorrectly when counting back).

Appropriate Lead Time but too short

"1" if the subject attempts appropriate lead time calucations for all items, in relationship to the appropriate "parent", but tends to make all lead times too short

Appropriate Lead Time but too Long

"1" if the subject attempts appropriate lead time calucations for all items, in relationship to the appropriate "parent", but tends to make all lead times too long, stretching out the normal MRP schedule.

Appropriate gets redundancy

"1" if shows an understanding that items combined to make other items do not both have to be purchased, or scheduled for work orders. Considers how items on different levels affect each other.

Two to one

"1" if accurately represents parent/child relationships in which two or more parts combine to make a object at another level.

One to One

"1" if accurately represents parent/child relationships in which one parts changes to make a different object at another level. Do not code for the Button Top Pen task!

Total:

Add up all "1's". For the converted proportion, divide total by 12 (11 for the button top pen).

Does the S. make the object concrete?

"1" if the S. insists on knowing what the item is, or indicates that the schedule can't be done unless he/she knows what the item is. Also if the S. invents an item and parts that the problem might represent. Not applicable to Pen and Ship.

Coding Instructions:
Tree Question

MRP Based

"1" if the subject attempts to calculate the materials required to complete the specified number of end items.

Sample Indicators:

1. asks if there are already any parts in stock
2. follows the tree downward to determine what items make up what other items.

Manufacturing Based

"1" if the subject attempts to calculate how many items go into one end item (divides). Adds all items without regard to redundancy, or adds onto the quantities indicated. Indicates he needs to know that the item is and how it is made before he can answer.

First answer The subject's total
Second answer The subject's second answer, if there is one
Subsequent Ans. Any additional answer.

Full redundancy:

"1" if the subject indicated through talk or adding strategy that he or she understood the implications both one->two and one->one redundant structures in the tree (even if added incorrectly)

Partial redundancy:

"1" if the subject indiated through talk or adding strategy that he or she understood the implications of at least one of the following kinds of item structure redundancies: one->two, one->one or part->whole.

Pre-test Coding Form
Card Sort for "unknown" object

Subject name ______________________________
Training Group __________

MRP Orientation? _____
- top down? _____
- By Levels? _____
- Goes Into? _____
- Symmetrical? _____

Total: _____

converted proportion: _____

Manufacturing
Orientation? _____
- Horizon? _____
- Linear? _____
- Infers process _____
- Assy Clusters? _____

Total: _____

converted proportion: _____

Info used/mentioned:
- Names _____
- Levels _____
- Num Seq. _____
- Num meaning _____
- Used in _____

Does the S. make the object concrete? _____

It it an integrated sort? _____

Coding Form
Pre-test Scheduling question
Scheduling unknown abstract

Subject name ________________________________
Training Group __________

Manufacturing Orientation? _____
- Capacity? _____
- Bottom up? _____
- Begins in Jan _____
- Infers linear process _____

Total: _____

converted proportion: _____

MRP Orientation? _____
- schedules back frim E.I.? _____
- All LT. Accur? _____ (If yes, assign six points and go to "quantity per". If no, continue)
- Some LT concept _____ From strategy or talk during strategy.
- All LT relative to zero? _____
- Approp. LT but miscalc _____
- Approp LT but too long _____
- Approp LT but too short _____

Appropriately gets redundancy _____
- Two to one _____
- One to one _____

Qty per accurate? _____

Makes A concrete? _____

converted proportion: ______

Does the S. make the object concrete? ______
It it an integrated sort? ______

Pre-test Coding Form
Tree with quantities

Subject name ______________________________

Training Group __________

Strategy for calculation:

MRP based? ________
Man. based? ________
Int? ________

First Ans? ________
Subseq. ans? ________
subseq. ans? ________

Full Redun? ________
Partial? ________

Makes Object Concrete? ________

Post-test Coding Form
Card Sort for "unknown" object

Subject name ________________________________

Training Group __________

MRP Orientation? _____
- top down? _____
- By Levels? _____
- Goes Into? _____
- Symmetrical? _____

Total: _____

converted proportion: _____

Manufacturing Orientation? _____
- Horizon? _____
- Linear? _____
- Infers process _____
- Assy Clusters? _____

Total: _____

converted proportion: _____

Info used/mentioned:
- Names _____
- Levels _____
- Num Seq. _____
- Num meaning _____
- Used in _____

Does the S. make the object concrete? _____

It it an integrated sort? _____

Post-test Coding Form
Card Sort for "Ship"

Subject name ______________________________

Training Group __________

MRP Orientation? _____
- top down? _____
- By Levels? _____
- Goes Into? _____
- Symmetrical? _____

Total: _____

converted proportion: _____

Manufacturing
Orientation? _____
- Horizon? _____
- Linear? _____
- Infers process _____
- Assy Clusters? _____

Total: _____

converted proportion: _____

Info used/mentioned:
- Names _____
- Levels _____
- Num Seq. _____
- Num meaning _____
- Used in _____

Does the S. make the object concrete? _____

It it an integrated sort? _____

Coding Form
Post-test Scheduling question
Scheduling unknown abstract

Subject name ______________________________

Training Group __________

Manufacturing
Orientation? ______
- Capacity? ______
- Bottom up? ______
- Begins in Jan ______
- Infers linear process ______

Total: ______

converted proportion: ______

MRP Orientation? ______
- schedules back frim E.I.? ______
- All LT. Accur? ______ (If yes, assign six points and go to "quantity per". If no, continue)
- Some LT concept ______ From strategy or talk during strategy.
- All LT relative to zero? ______
- Approp. LT but miscalc ______
- Approp LT but too long ______
- Approp LT but too short ______

Appropriately gets redundancy ______

- Two to one ______
- One to one ______

Qty per accurate? ______

Makes A concrete? ______

converted proportion: ______

Does the S. make the object concrete? ______
It it an integrated sort? ______

Coding Form
Post-test Scheduling question
Scheduling "Model One Ship"

Subject name ______________________________
Training Group __________

Manufacturing
Orientation? _____
- Capacity? _____
- Bottom up? _____
- Begins in Jan _____
- Infers
linear process _____

Total: _____

converted proportion: _____

MRP Orientation? _____
- schedules
back frim E.I.? _____
- All LT. Accur? _____ (If yes, assign six points and go to "quantity per". If no, continue)
- Some LT concept _____ From strategy or talk during strategy.
- All LT relative to
zero? _____

- Approp. LT but
miscalc _____

- Approp LT but
too long _____

- Approp LT but
too short _____

Appropriately gets
redundancy _____

- Two to one _____
- One to one _____

Qty per accurate? _____

Makes A concrete? _____

converted proportion: ______

Does the S. make the object concrete? ______
It it an integrated sort? ______

Coding Form
Post-test Scheduling question
Scheduling "Button Top Pen"

Subject name ____________________________________

Training Group ____________

Manufacturing
Orientation? ______
- Capacity? ______
- Bottom up? ______
- Begins in Jan ______
- Infers
  linear process ______

Total: ______

converted proportion: ______

MRP Orientation? ______
- schedules
  back frim E.I.? ______
- All LT. Accur? ______ (If yes, assign six points and go to "quantity per". If no, continue)
- Some LT concept ______ From strategy or talk during strategy.
- All LT relative to
  zero? ______
- Approp. LT but
  miscalc ______
- Approp LT but
  too long ______
- Approp LT but
  too short ______

Appropriately gets
redundancy ______

- Two to one ______
- One to one ______

Qty per accurate? ______

Makes A concrete? ______

converted proportion: ______

Does the S. make the object concrete? ______
It it an integrated sort? ______

Post-test Coding Form
Tree with quantities

Subject name ______________________________

Training Group __________

Strategy for calculation:

MRP based? ________
Man. based? ________
Int? ________

First Ans? ________
Subseq. ans? ________
subseq. ans? ________

Full Redun? ________
Partial? ________

Makes Object Concrete? ________

Coding Form
Post-test Scheduling question
Scheduling "Model One Ship"

Subject name MRP Strategy
Training Group ____

Manufacturing
Orientation? 0
- Capacity? 0
- Bottom up? 0
- Begins in Jan 0
- Infers linear process 0

Total: 0
converted proportion: 0

MRP Orientation? 1
- schedules back frim E.I.? 1
- All LT. Accur? 6 (If yes, assign six points and go to "Appropriately gets redun...". If no, continue)
- Some LT concept — From strategy or talk during strategy.
- All LT relative to zero? —
- Approp. LT but miscalc —
- Approp LT but too long —
- Approp LT but too short —

Appropriately gets redundancy 1

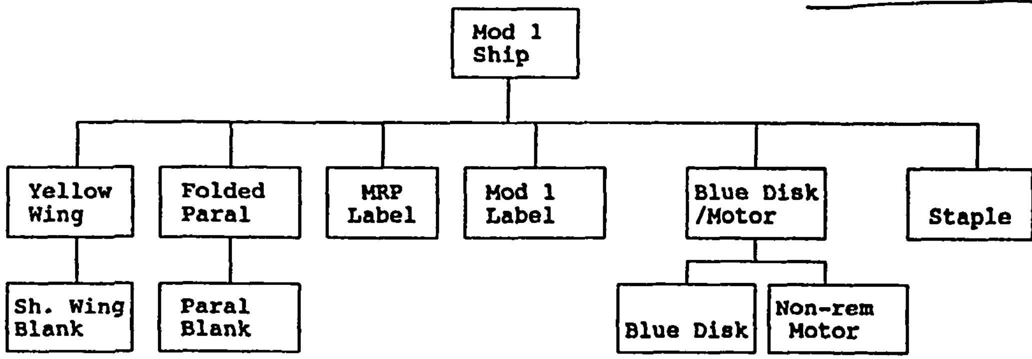
- Two to one 1
- One to one 1

Qty per accurate? 1

Total: 12
converted proportion: 1.0

Does the S. make the object concrete? NA
It it an integrated sort? 0

MRP Strategy



Item #	Description	Relative Level	Lead Time	Quantity Per
000.10	Starship, Model 1	0	1 week	
004.10	Wing, Short Yellow	1	1 week	2
009.22	Wing, Short Blank	2	1 week	1
002.10	Folded Parallelogram	1	1 week	1
009.21	Parallelogram Blank	1	1 week	1
009.04	MRP Game Label	1	2 weeks	1
009.01	Label: Model 1	1	2 weeks	1
001.10	Blue Disk/Motor Ass'y	1	1 week	1
003.10	Blue Disk	2	1 week	1
003.60	Motor, Non-Remov	2	3 weeks	2
009.05	Staples	1	1 week	2

Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7 *	Week 8
	3.60 x 200 →		P.O.'s 9.04 x 200 → 9.01 x 200 → 9.22 x 400 → 9.21 x 200 → 3.10 x 200 →	4.10 x 200 → 2.10 x 200 → 1.10 x 100 9.05 x 200	Assemble Mod 1 200 →	Finished Ship	

Coding Form
Post-test Scheduling question
Scheduling "Model One Ship"

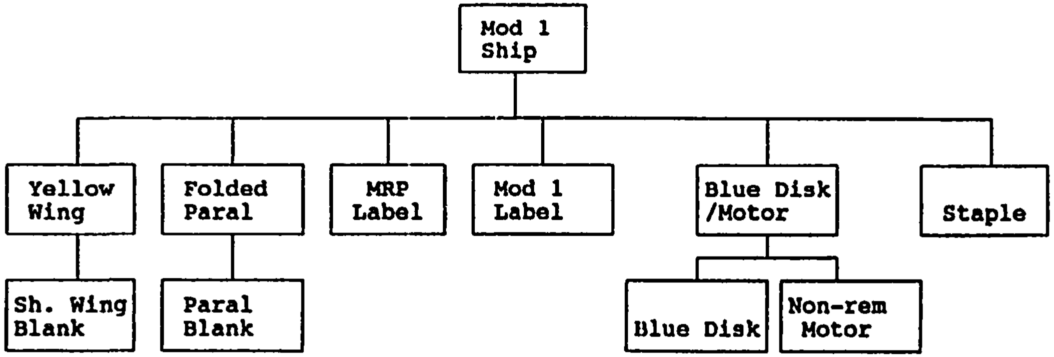
Subject name Mixed Strategy
Training Group ____________

Manufacturing Orientation?	.5
- Capacity?	1
- Bottom up?	0
- Begins in Jan	0
- Infers linear process	0
Total:	1.5
converted proportion:	.30

MRP Orientation?	1	
- schedules back frim E.I.?	1	
- All LT. Accur?	0	(If yes, assign six points and go to "Appropriately gets redun...". If no, continue)
- Some LT concept	1	From strategy or talk during strategy.
- All LT relative to zero?	0	
- Approp. LT but miscalc	1	
- Approp LT but too long	–	
- Approp LT but too short	–	
Appropriately gets redundancy	1	
- Two to one	1	
- One to one	1	
Qty per accurate?	1	
Total:	8	
converted proportion:	.66	

Does the S. make the object concrete? NA
It it an integrated sort? 1

Mixed Strategy



Item #	Description	Relative Level	Lead Time	Quantity Per
000.10	Starship, Model 1	0	1 week	
004.10	Wing, Short Yellow	1	1 week	2
009.22	Wing, Short Blank	2	1 week	1
002.10	Folded Parallelogram	1	1 week	1
009.21	Parallelogram Blank	1	1 week	1
009.04	MRP Game Label	1	2 weeks	1
009.01	Label: Model 1	1	2 weeks	1
001.10	Blue Disk/Motor Ass'y	1	1 week	1
003.10	Blue Disk	2	1 week	1
003.60	Motor, Non-Remov	2	3 weeks	2
009.05	Staples	1	1 week	2

Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
		9.04 x 200 9.01 x 200 9.22 x 400 9.21 x 200 3.10 x 200 3.60 x 200	4.10 x 400 2.10 x 200 1.10 x 200 9.05 x 200	Assemble 100 ships	Assemble 100 Ships	Due Date For Ship	

Coding Form
Post-test Scheduling question
Scheduling "Model One Ship"

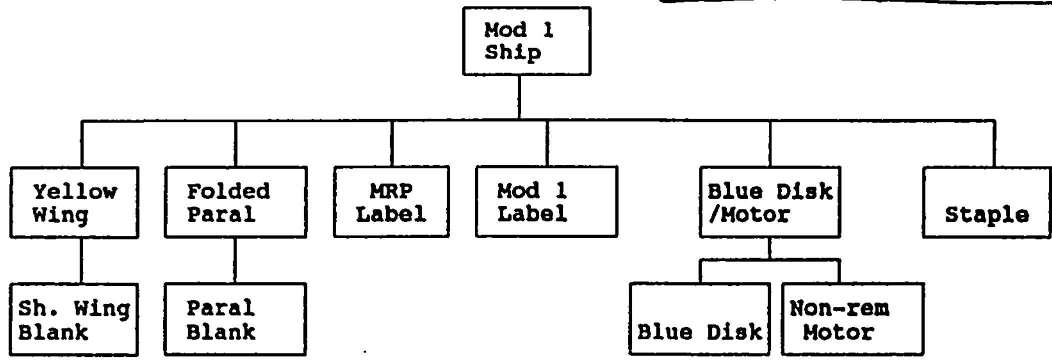
Subject name Traditional Manufacturer
Training Group ____

Manufacturing Orientation?	1
- Capacity?	1
- Bottom up?	1
- Begins in Jan	1
- Infers linear process	1
Total:	5
converted proportion:	1.00
MRP Orientation?	0
- schedules back frim E.I.?	0
- All LT. Accur?	0
- Some LT concept	-
- All LT relative to zero?	-
- Approp. LT but miscalc	-
- Approp LT but too long	-
- Approp LT but too short	-
Appropriately gets redundancy	0
- Two to one	0
- One to one	0
Qty per accurate?	1
Total:	1
converted proportion:	.08

(If yes, assign six points and go to "Appropriately gets redun...". If no, continue)
From strategy or talk during strategy.

Does the S. make the object concrete? NA
It it an integrated sort? 0

Traditional Manufacture Strategy



Item #	Description	Relative Level	Lead Time	Quantity Per
000.10	Starship, Model 1	0	1 week	
004.10	Wing, Short Yellow	1	1 week	2
009.22	Wing, Short Blank	2	1 week	1
002.10	Folded Parallelogram	1	1 week	1
009.21	Parallelogram Blank	1	1 week	1
009.04	MRP Game Label	1	2 weeks	1
009.01	Label: Model 1	1	2 weeks	1
001.10	Blue Disk/Motor Ass'y	1	1 week	1
003.10	Blue Disk	2	1 week	1
003.60	Motor, Non-Remov	2	3 weeks	2
009.05	Staples	1	1 week	2

Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
9.22 x 400 9.21 x 200 9.04 x 200 9.01 x 200 3.10 x 200 3.60 x 200 9.05 x 400	make 40 Ships	make 40 Ships	make 40 Ships Send 80 Ships	Make 40 Ships	Make 40 Ships	Send 120 Ships	

Appendix C.

Description of the MRP workshops:

Two days of being a computer

Constructive Activities are assumed to assist in knowledge reorganization

The workshops used with subjects were developed after months of analysis with the help of an MRP expert and others familiar enough with MRP logic to recognize activities and behavior that most richly represented the core logic of MRP systems. The assistance of noted MRP experts as well as the researchers' extensive knowledge and experience with different MRP systems (from previous research) assisted considerably in the process of isolating the goals and activities that would exert the most developmental impact. Considerable effort also went into developing tools, forms and other devices that the participants could use to construct their factory with, and in the second phase of the workshop, construct their manual MRP system.

Assumptions of workshop construction

The workshop was constructed with the goal of examining the relationship between activity and knowledge reorganization/acquisition. It was also constructed to test the assumption that conceptual reorganization involves both the deconstruction of preconscious assumptions and the reorganization of existing knowledge into new or refined ways of thinking and that deconstruction of old notions is best effected through activity. Therefore, the workshop began with activities that would allow the participants to make their current "default" strategies explicit and examine the portions that were inappropriate. Following those activities, participants constructed an alternative approach by literally "constructing" a manual MRP system and carrying out the logic of an MRP system, as a group. In other words, before getting on the computer, participants functioned as the computer.

The impact of activity on specific core concepts.

Previous work in MRP learning shows that, of the three core concepts, the notion of "virtual quantity" is acquired first and "phased time" is the most difficult to grasp. This makes sense given that, on a day to day basis, most people in manufacturing environments are concerned with goals and activities which are affected by how the system is calculating the quantities available to do work. However, if constructive activities have special capacity to shape development, excluding constructive activities having to do with "relative quantity" should alter this normally observed trend, especially if more opportunities are provided (than normally occur at work) to construct conceptsof "phased time" and "hierarchical item". Therefore, although every effort was made to include in the workshop equal numbers of activities, workbook material and lecture time for each concept area, there were constructive activities for only "time" and "item" (i.e., activities designed to engage workers in activities that would lead them to construct the concepts of phased time and hierarchical item). In as much as it was possible (given the intertwined nature of the concepts), constructive activities exposing the logic of "virtual quantities" was avoided. In constrast, activities having to do with quantity were highly procedural, presenting participants with a "right" way to calculate quantities with no encouragement to allow them to "invent" or "construct" virtual quantity principles or algorithms.

Below ("Description of all activities") is a detailed description of all activities and an explanation of how they are "Quantity" "time" or "item" oriented and either "constructive" or "procedural".

Materials and rules for the "Starship" factory

The factory workshop was presented to the participants as a "game", challenging them to run the factory within certain, specific constraints. Their goal was to run the factory at a profit, and do so by keeping inventory low, delivery to customers prompt, and quality high. Participants were free to assign roles and organize themselves according to any organizational scheme. After an initial "set up" period in which they defined and chose roles and discussed business strategy, the workshop was started and they were given their first crop of customer orders, a fixed amount of cash (the operating budget) and copies of outstanding purchase orders for materials requested by a fictional predecessor.

Once the factory was running, each "week" was 20 minutes long. The game was "rigged" so that participants would run into financial or delivery problems if they did not plan according to strict MRP planning principles. However, it was also designed so that "failure" could take place in a number of ways, and in a such a way that revealed the group's assumptions about manufacturing, purchasing and planning and their default decision making strategies.

Some of the materials for the starship factory are included at the end of this appendix. The materials consisted of three different models of an origami paper starship, a styrofoam "stockroom", customer orders (on customer order forms), open purchase orders for three weeks, blank purchase order forms for ordering more material, a "catalogue" of parts and assemblies that can be used to the make the starship and forms for scheduling purchasing and shop production. Importantly, the three starship models had shared, partially shared (shared by only two models) and unique parts between them. The "MRP" system is comprised of Item master and Bill of Material Forms with attached worksheets. When these forms are completed with the necessary data, they can be used together to hold the data and execute the planning calculations normally done within an MRP system, comprising a manual MRP system. A full set of the completed forms is included in this appendix.

Support from Macola Inc.

Macola Inc. (the MRP software package that the TA decided to use) agreed to donate a copy of the system for research purposes. The system was installed by a vendor on the university's central LAN. All workshop activities were checked against the finer points of the logic as it is represented in this system. In addition, the system was used to calculate "ideal outcomes" of workshop activities for use as feedback in the workshops. Once the TA's system was installed, dial-in access was arranged so that the researcher could communicate with subjects and observe any changes being made in their MRP system (such as the input of data, setting up of file structures, etc.)

Description of all Activities

Below is the list of the activities over two days and the concepts targeted. Following this list is a detailed description of each activity and how it is either "constructive" or "procedural".

Day One:

1. Introduction to the starship factory and its goals
2. Organizing a planning and production system
3. The game begins; running the factory for 6-8 twenty minute periods
4. Discussion: What happened; let's take a look at our plan, our resources and compare it all to what the previous owner would have done. What is the strategy we defaulted to?
5. Lecture and Slides: Inventory concepts, MRP concepts.
6. Discussion: Maybe there is an alternative:
   MRP -- what it does
   MRP -- what is requires: BOMs, Item Masters,
7. ITEM Activity: Exploding the ship/inventing an item structure
8. ITEM/TIME Activity: Creating Item masters as a way of telling MRP what to think about/when to think about it.
9. ITEM/TIME Activity: Constructing BOMs that make MRP sense
10. TIME Activity: Putting a master schedule on the Item master worksheets that will allow the system to recommend a plan

DAY TWO:

11. Quantity Activity: Entering in the "on hand" and "on order". Doing the calculation (regeneration) the MRP system does when it regenerates its recommendations using your master schedule.
12. TIME/ITEM/QUANTITY Activity: Translating the plan that MRP generated to a "buy" and "build" plan for the next eight weeks.
13. Building according to this plan
14. Calculating assets again.
15. Discussion: Comparing the first plan and its results to the new plan. What is different? How was it to build according to the second plan? What has changed?
16. Discussion: Improving upon the new ways. MRP is somewhat rigid; how can that be dealt with?

Day One:

1. <u>Introduction to the starship factory</u>:

Participants are informed that they will be "taking" over a factory that has managed to make a sizable profit by keeping around only that inventory which will be needed soon, thereby not tying up cash in unneeded supplies. It is explained that their goal is to continue increasing their cash while keeping inventory low. Participants are introduced to the starship (as an object), shown how it is made, and permitted to practice assembly, painting and receive feedback on whether or not their ships are "saleable". They are also briefed on the game's rules, material ordering procedures, and customer order procedures.

2. <u>Organizing a planning and production system</u>

The six to eight participants are told they need to organize themselves to meet the customer orders, keep track of inventory, handle purchasing, budgeting and vendor relationships. They are given about 20 minutes to jointly organize themselves.

3. <u>The game begins; running the factory for 6-8 twenty minute periods</u>

During this portion, the participants are given the customer orders, the copies of the outstanding purchase orders that had been sent to the vendor (for material their predecessor ordered) and their cash budget. Subjects are also given forms for documenting their buy and build schedules, P.O. forms for ordering from the vendor and blank paper for developing any other forms or record keeping devices they might want to use. (See back of this appendix for materials) Importantly, they have exactly enough on-hand material, cash and material-on-the-way to meet their current customer orders and continue to make a profit, but only if they function with a classic MRP plan. This "rigging" more or less ensures that only those subjects who have some understanding of MRP or some kind of forward planning will do well. The subjects' orders for material, cash flow from week to week and quantity and quality of delivered material are recorded by an experimenter.

Usually during the third or fourth period, the subjects realize they are running into trouble and begin to devise strategies for getting themselves out. The stress of the time limits usually elicits "default" strategies, and it is at this point of the activities that subjects' work history becomes most evident. For example, shop floor workers attempt to deal with the crisis by accruing "critical" parts with their available cash. In addition, they attempt to step up and better organize production practices, so they can make more and better ships in less time. Importantly, this amounts to "cheating" on lead times established for each task. The main concern organizing their activity is getting the right number of quality ships to the customer, at all costs, rationalizing that if they don't produce they won't make money anyway. They are more likely to borrow money from the vendor (at 20% interest per 20 minute period). In contrast, planners, managers and other "office" personnel tend to try to solve the problem by controlling the budget and are less concerned with shipping on time than with going broke. They will make the customer wait, attempt to bargain with the vendor and sometimes take too long to make decisions about spending; e.g., by the time they decide what to buy, another "week" has passed and they have pushed back delivery even further. As these "default" strategies emerge under stress, the workshop leader attempts (as unobtrusively as possible) to trigger discussion on what the group is doing and encourages them to discuss their decisions and make them together. The purpose of this activity is begin the process of making the implicit into the explicit, or help the participants develop a conscious awareness of the preconscious assumptions which influence their manufacturing strategies and decisions.

4. Discussion: What happened; let's take a look at our plan, our resources and compare it all to what the previous owner would have done. What is the strategy we defaulted to?

The Game is stopped when one of three things happens: when the participants cannot meet any orders or do not have the appropriate material to build what is required for delivery (they have nothing to do); when they are so deeply in debt that it has become obvious to the participants that they are continuing on a spiral downward; they have begun arguing and the game has become very stressful.

At this point, participants are given a form that allows them to tally their assets (all material in the stockroom and all cash). In addition, they fill out a similar form tallying their "losses", including "lost opportunity" in the form of orders that the customer cancelled because they would not be ready on time. Included in the "losses" are materials that were damaged, rejected because of poor workmanship, or even machine breakdown (staples lost when the stapler jammed).

Once all the forms are filled out, subjects are shown what the "previous owner" would have done and what the differences would have been in terms of cash on hand and items in the stockroom. The workshop leader initiates a discussion among the participants of what happened, asking "what was your strategy, what were you thinking that led to take the actions shown on your forms?" and "what do you think you did well?"

The purpose of this form-filling and discussion activity is to get participants to verbalize their default strategies, especially any strategies that are group based; since the participants were almost always people who routinely work together and solve problems as a group in the shop, they are likely to replicate a group approach they may already share. However, they also already have a common language and the discussion becomes a collective reconstruction of the group's normal ways of functioning and dealing with pressure.

5. Lecture and Slides: Inventory concepts, MRP concepts.

The participants then receive a slide lecture/discussion about MRP, it's general goals, properties and an introduction into some of its data structures. This lecture covers all MRP core concepts, and specifically introduces the ways that the system "thinks about" time, items and quantities in general. Its main purpose is to introduce a new set of terms for participants.

6. Discussion: Maybe there is an alternative:

The lecture ends with the workshop leader asking the group to consider what might be a viable alternative. At this point participants often verbalize different goals or subgoals than they did before, such as "forward planning", or "keeping inventory balances".

7. ITEM Activity: Exploding the ship/inventing an item structure:

After a brief discussion of the logical necessity of hierarchical item structures in MRP, participants are asked make an item structure for the starship, using actual parts that they can glue onto foam board. They are asked to represent the item the way "MRP would need to think about it". This activity is done in pairs. Each pair then presents their item structure to the rest of the group and explains the flow between levels, the reasons given items are put on given levels, in the sequence represented, etc. At the end of this exercise, the workshop leader presents an item structure that is known to work well in an MRP system and asks the participants to compare it with what they did and discuss the differences.

The purpose of this activity is to get participants actively involved in conceptualizing how specific objects ought to be handled in an MRP system, with efficient production and the accurate calculation of material as goals. The "constructive" aspect involves the literal formulation of a structure and then verbally justifying and explaining one's choices in the design.

8 & 9. ITEM/TIME Activity: Creating Item masters as a way of telling MRP what to think about/when to think about it.: ITEM/TIME Activity: Constructing BOMs that make MRP sense.

The participants are then asked to actually begin setting up a manual MRP system, using forms that hold the data in a format similar (in terms of the functional logic) to what an MRP system would have. They are given blank Bill Of Material and Item Master Forms and asked to choose which items require a BOM and which require an item master. That is, what "items" does the system need defined, how they should be defined. Conversely, subjects are encouraged to think about what items the system does not need to think about in its representation of the goods and parts in the factory (i.e., what needs an Item master) and what relationships between parts and parts, and parts and finished goods does it need to know about to be a useful tool to this group (i.e., what relationships need BOM's). Part of filling out the item masters also involves making decisions about how much "lead time" each part, subassembly and end item needs, what forms things take (do they come in lots of 10, 100 or individually), the item's "level", and whether it ought to be purchased or made. In other words, the participants define the relevant objects and the relevant relationships between objects. Again, they are called upon to explain their choices and discuss decisions.

The "constructive" portion of this activity resides mainly in the decision making about what portions of the "real" world (of the starship factory) need to be represented in the "MRP" world. For example, most participants realize during this activity that not all phases of production need to be represented in MRP, but only those phases which could potentially involve restocking an item or changing what it's going to be (e.g., in the case of a part or raw material that could be used in or transformed into more than one kind of higher level assembly). For example, many realize at this point that the folded but unpainted wings do not need to be represented, because if they are "long wings" they are always green, and if they are "short" wings, they are always yellow. Therefore it easier to fold and paint wings in one step and represent only two objects in MRP: the raw material for wings and the finished wings. If short wings were sometimes also green (e.g., for a fourth model of ship) then short wings that are unpainted would have be represented so that the system could allocate the right quantities of partial assemblies for painting green and yellow right before they are needed.

10. TIME Activity: Putting a master schedule on the item master worksheets that will allow the system to recommend a plan:

Participants then translate the customer orders into a master schedule and decide where to put this information on the worksheets, and which item master worksheets to put it on (which items do the human beings make decisions about?). Participants are, again, asked to imagine themselves as the computer and asked what information about demand they would need and where would have to go to be the most useful. Participants usually realize at this point that, given that MRP knows what goes into what, it only needs to know the demand for the finished goods, and will take over the calculation from there. Therefore, independent schedules do not have to entered into the forms for the parts and subassemblies of the starship.

The constructive component of this activity resides in the group decision making process of what kinds of data to enter as a master schedule and where to get it (the customer's orders). There is also some procedural instruction on where to put the information on the forms (which boxes) once participants have decided what to use.

Day Two

11. Quantity Activity: Entering in the "on hand" and "on order". Doing the calculation (regeneration) the MRP system does when it regenerates its recommendations using your master schedule.

During this activity, subjects actually do the calculation that MRP normally does during a regeneration. This includes putting in the "on hand" and "virtually on hand" quantities in the correct cells on the forms and doing all the "explosion" down through all levels. The math involved in this step is rather extensive and time consuming and this activity can take a couple of hours. The participants are not permitted to invent the method of calculation, speculate on an alternative or discuss where to put the on hand and virtually on hand quantities. Instead, they are shown the rote procedures for doing all of this.

12. <u>TIME/ITEM/QUANTITY Activity: Translating the plan that MRP generated to a "buy" and "build" plan for the next eight weeks.</u>

At the end of the regeneration, the "bottom line" (the Planned Order Release Recommendations at the bottom of each sheet) of each worksheet represents MRP's recommended actions for all buying and building for each week. Subjects are asked to translate this plan to the buy and build schedule form or to some other form of shop floor schedule and purchase order forms.. They are then asked to compare it to their first buy and build schedule. They discuss the differences and speculate on "what MRP is thinking" to generate the plan that it did. They are asked if there are any changes they would make to this plan (e.g., to spread work out more evenly). The "constructive" aspect of this activity resides mainly in the discussion, and to a lesser extent, in the transfer of the MRP generated recommendations to a schedule that can be evaluated for its reasonableness.

13. <u>Building according to this plan.</u>

Time permitting, participants build according to this plan. One of the persistent comments with this activity is that building and buying are now "boring" because there is no panic, rush or uncertainty. The purpose of the activity is expose participants to an opportunity to organize themselves according to a "plan" vs according to a "crisis", and to show the relationship between "theory" and "practice".

14. Calculating assets again.

Participants use the same form as in the first iteration to calculate losses, assets and cash. They are given back their purchase orders, production schedules and cash flow records from the first day and asked to compare the strategies represented from the first day with those represented on the second day.

15. Discussion: Comparing the first plan and its results to the new plan and its results. What is different and what differences in strategy can be seen in the results? How was it to build according to the second plan? What has changed?

The workshop leader initiates a discussion about how the first day and second day differ, how do participants think they have changed, what beliefs about timing, items and quantities (how to have on hand, for example) have changed, if any. At this point, participants get the opportunity to compare old beliefs/assumptions with things they are thinking now.

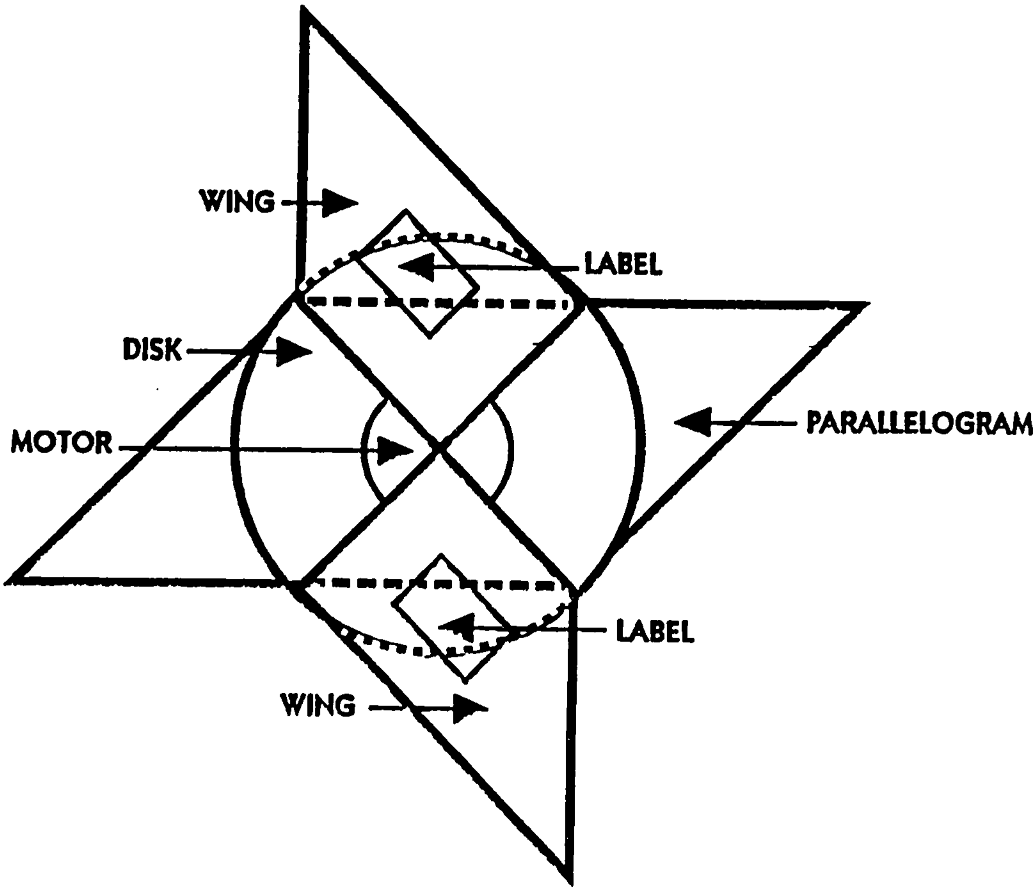
16. Discussion: Improving upon the new ways. MRP is somewhat rigid; how can that be dealt with?

The workshop leader initiates one last discussion, although usually it arises spontaneously. How does these ways of thinking apply to what goes on at the TA? How should MRP be tailored or changed to fit some of the problems there, or even in the problems encountered in the workshop. What are ways to powerfully use MRP as a tool for real work.

Samples of Workshop lecture material

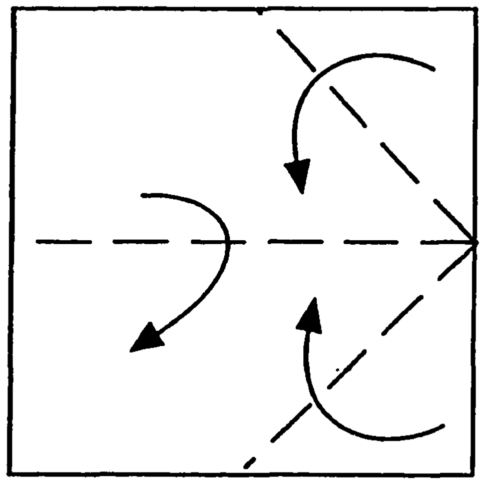
and activity "props"

STARSHIP



STARSHIP

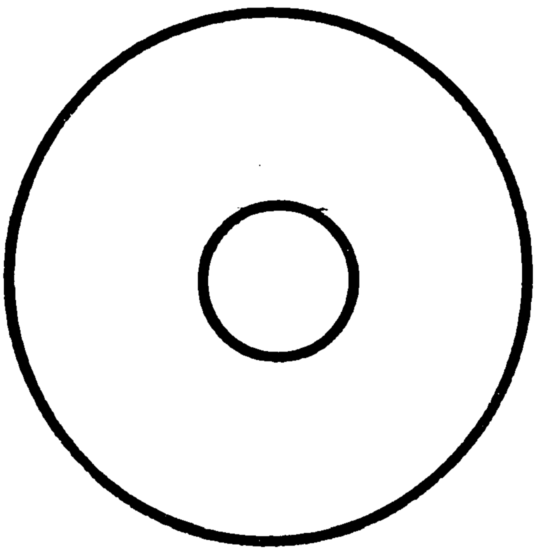
WING



1. Cut Square 10 Blocks On a Side (or purchase wing stock)
2. Fold Center Line and Open Again
3. Fold Two Corners To Center Line
4. Close Center Fold
5. Paint Appropriate Color

STARSHIP

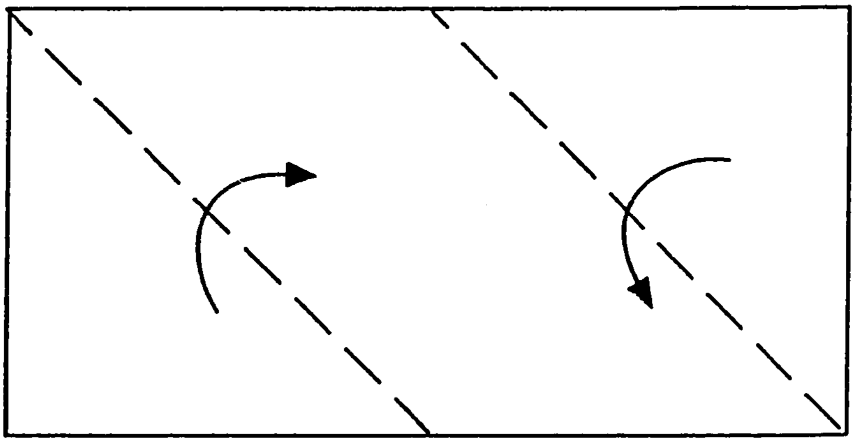
Disk Motor Assembly
COLORED DISK



1. Draw Circle With 5 Blocks Radius
2. Cut Out Circle (or purchase disk)
3. Install Appropriate "Motor" In Center of Disk

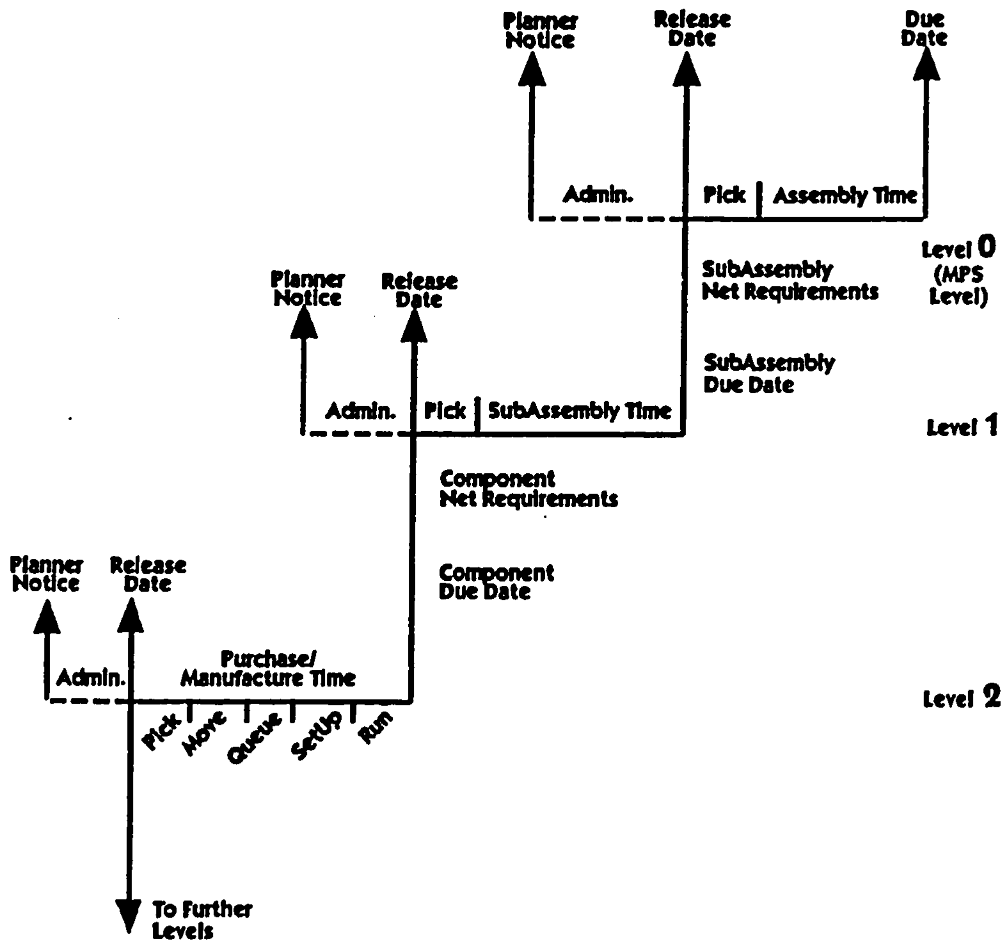
STARSHIP

PARALLELOGRAM



1. Cut Out Rectangle 10 Blocks Wide by 20 Blocks Long (or buy rectangle stock)
2. Fold Over Two Opposing Corners To Form Parallelogram

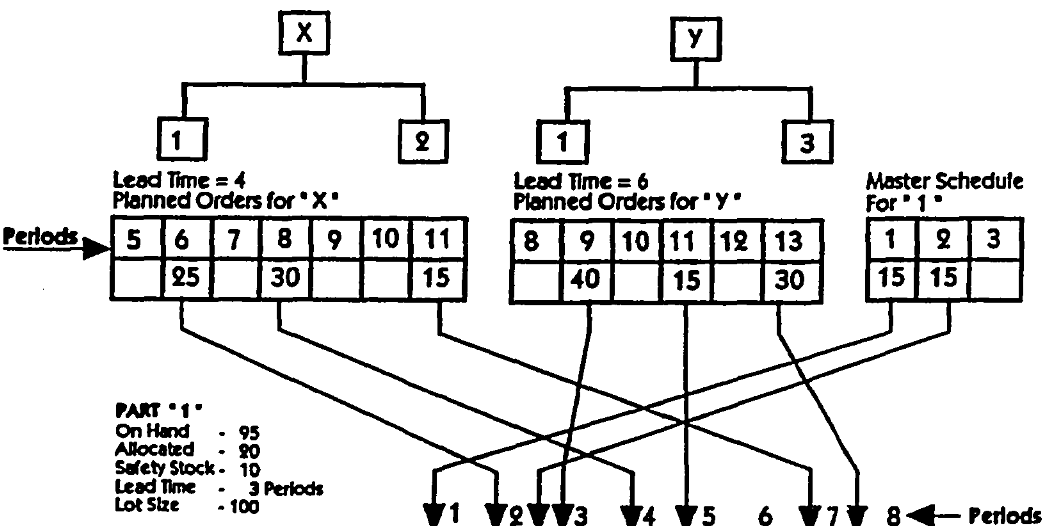
CUMULATIVE LEAD TIME



Backward Scheduling Applications:
1. Manufacturing
2. Repair Where Delivery Is Absolute

TIME-PHASING

MANUFACTURING MATERIALS



	1	2	3	4	5	6	7	8
Gross Requirements	15	40	40	30	15		45	
Scheduled Receipts			100					
Projected On Hand	60	20	80	50	35	35	(10) 90	90
Net Requirements							20	
Plan-Order Receipts							100	
Plan-Order Releases				100				

REPAIR/REFURBISH CHART

	MODEL I (Yellow Wings)	MODEL II (Green Wings)	MODEL III (Green Wings)
White Parallelogram	ReUsable If OK	Replace 20%	Replace 20%
Disk	Replace 100%	Replace 100%	Replace 20%
Motor	Replace 100%	Replace 100%	Replace 30%
Motor/Disk on Scheduled Maint	Replace with new assy	Replace with new assy	Replace motor only
Wing with MRP Game	Replace 100%	Replace 5%	Replace 20%
Wing with Date	Replace 100%	Replace 100%	Replace 100%
Staples	Replace 100%	Replace 100%	Replace 100%

MRP GROSS-TO-NET LOGIC

Available Inventory - Total Requirements = Projected On-Hand

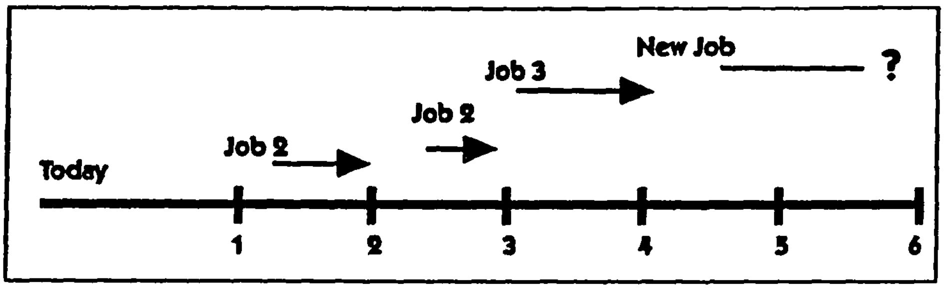
OR

On-Hand + Scheduled Receipts = Available Inventory

MINUS = Projected On-Hand

Gross Requirements + Allocations = Total Requirements

FORWARD SCHEDULING



Considerations:

- What Jobs are Currently on the Schedule?
- When Do They Finish?
- When Will Material Be Available?

Forward Scheduling Is Used For:

- Emergency Planning
- Job Shops
- Certain Repair Shops, Cars, Appliances, etc.

GAME RULES

PRODUCT BUILT AS PER SAMPLE WITH GOOD QUALITY

- SUB-STANDARD WORK WILL BE REFUSED

SUB-ASSEMBLIES BUILT ACCORDING TO LEAD TIMES

- **SUB-ASSEMBLIES CANNOT BE BUILT WITHIN THE SAME PERIOD AS THE ASSEMBLY THEY ARE USED IN**

FINISHED PRODUCTS DELIVERED BEFORE THE END OF PERIOD DUE

- PENALTY FOR LATE DELIVERY

SUB-STANDARD RAW MATERIAL REPLACED WITHIN DELIVERY PERIOD

- BAD MATERIAL DISCOVERED LATER MUST BE REORDERED WITHIN NORMAL LEAD TIMES

QUESTIONS ABOUT GAME CAN BE ASKED AT ANY TIME

MRP

PARTS, PRICES, AND LEAD TIMES

PART#	DESCRIPTION	PRICE	LEAD TIME (WKS)	
000.10	STARSHIP, MODEL 1	$110.00	1	ASSY
000.20	STARSHIP, MODEL 2	$122.00	1	ASSY
000.30	STARSHIP, MODEL 3	$150.00	1	ASSY
002.10	FOLDED PARALLELOGRAM	$ 6.00	1	ASSY
001.10	BLUE DISK/MOTOR ASSY	$ 72.00	1	ASSY
001.20	ORNG DISK/MOTOR ASSY	$ 72.00	1	ASSY
001.30	RED DISK/MOTOR ASSY	$ 96.00	1	ASSY
004.10	WING, SHORT, YEL	$ 9.00	1	ASSY
004.20	WING, LONG, GRN	$ 14.00	1	ASSY
003.10	DISK, BLUE	$ 30.00	1	PURCH
003.20	DISK, RED	$ 30.00	1	PURCH
003.30	DISK, ORNG	$ 30.00	1	PURCH
003.60	MOTOR, NON-REMOV	$ 42.00	3	PURCH
003.70	MOTOR, REMOVABLE	$ 66.00	3	PURCH
009.01	LABEL: MODEL 1	$ 2.00	2	PURCH
009.02	LABEL: MODEL 2	$ 2.00	2	PURCH
009.03	LABEL: MODEL 3	$ 2.00	2	PURCH
009.04	LABEL: MRP GAME	$ 2.00	2	PURCH
009.05	STAPLES (PK OF 30)	$ 30.00	1	PURCH
009.21	PARALLELOGRAM BLANK	$ 4.00	1	PURCH
009.22	WING, SHORT, BLANK	$ 2.00	1	PURCH
009.23	WING, LONG, BLANK	$ 2.00	1	PURCH

FINISHED ASSEMBLIES/PURCHASE PRICES

001.10P	BLUE DISK/MOTOR ASSY	$ 90.00	1	PURCH
001.20P	ORNG DISK/MOTOR ASSY	$ 90.00	1	PURCH
001.30P	RED DISK/MOTOR ASSY	$120.00	1	PURCH
001.40P	PARALLELOGRAM, FINISHED	$ 10.00	1	PURCH
001.50P	SHORT WING, FINISHED	$ 13.00	1	PURCH
001.60P	LONG WING, FINISHED	$ 20.00	1	PURCH

ORDER HISTORY

STARSHIPS

Part #	Description	Weeks							
		8	7	6	5	4	3	2	1
000.10	Starship, Model 1	2	4	1	1	3	4	2	1
000.20	Starship, Model 2	2	1	2	3	1	1	2	2
000.20	Starship, Model 3	0	0	1	1	2	0	2	3
	Total Starships	4	5	4	5	6	5	6	6

STARSHIP ORDER FORM

ORDER #: 1 **ORDER WEEK:** 1

PART#	DESCRIPTION	QTY	$EA	$TOTAL	WK DELY
001.10	STARSHIP, MODEL 1	1	110	110.00	
000.20	STARSHIP, MODEL 2	2	122	244.00	
000.30	STARSHIP, MODEL 3	2	150	300.00	

TOTAL: $654

STARSHIP ORDER FORM

ORDER #: 2 **ORDER WEEK:** 2

PART#	DESCRIPTION	QTY	$EA	$TOTAL	WK DELY
000.10	STARSHIP, MODEL 1	1	110	110 -	
000.20	STARSHIP, MODEL 2	3	122	366	
000.30	STARSHIP, MODEL 3	2		300 -	

TOTAL: $776.00

STARSHIP ORDER FORM

ORDER #: 3 **ORDER WEEK:** 3

PART#	DESCRIPTION	QTY	$EA	$TOTAL	WK DELY
00020	STARSHIP, MODEL 2	3	122	366.00	
000.30	STARSHIP, MODEL 3	3	150	450.00	

TOTAL: $816.00

STARSHIP ORDER FORM

ORDER #: 4 **ORDER WEEK:** 4

PART#	DESCRIPTION	QTY	$EA	$TOTAL	WK DELY
000.20	STARSHIP, MODEL 2	3	122	366.00	
000.30	STARSHIP, MODEL 3	4	150	600.00	

TOTAL: $966.00

STARSHIP ORDER FORM

ORDER #: 5 **ORDER WEEK:** 5

PART#	DESCRIPTION	QTY	$EA	$TOTAL	WK DELY
000.20	STARSHIP, MODEL 2	3	122	366.00	5
000.30	STARSHIP, MODEL 3	4	150	600.00	5

TOTAL: $966.00

STARSHIP ORDER FORM

ORDER #: 6 **ORDER WEEK:** 6

PART#	DESCRIPTION	QTY	$EA	$TOTAL	WK DELY
000.10	STARSHIP, MODEL 1	1	110	110.00	6
000.20	STARSHIP, MODEL 2	4	122	488.00	6
000.30	STARSHIP, MODEL 3	3	150	450.00	6

TOTAL: $1048.00

9

STARSHIP ORDER FORM

ORDER #: 7 **ORDER WEEK:** 7

PART#	DESCRIPTION	QTY	$EA	$TOTAL	WK DELY
000.10	STARSHIP, MODEL 1	1	110	110.00	
000.20	STARSHIP, MODEL 2	4	122	488.00	
000.30	STARSHIP, MODEL 3	4	150	600.00	

TOTAL: $1198.00

STARSHIP ORDER FORM

ORDER #: 8 **ORDER WEEK:** 8

PART#	DESCRIPTION	QTY	$EA	$TOTAL	WK DELY
000.10	STARSHIP, MODEL 1	1	110	110.00	
000.20	STARSHIP, MODEL 2	4	122	488.00	
000.30	STARSHIP, MODEL 3	3	150	450.00	

TOTAL: $ 1048.00

MRP GAME BILL OF MATERIAL

PARENT PART NO. ____________ LOW LEVEL CODE: ____________

TYPE OF BILL ( ) REGULAR ( ) PHANTOM · ( ) PLANNING

PART NUMBER	DESCRIPTION	QTY

PURCHASE ORDER

P.O. NUMBER:________

ORDER PERIOD:_____

PART NUMBER	DESCRIPTION	QTY	$/U	TOTAL$	L/T	DELY

PURCHASE ORDER

P.O. NUMBER: 1

ORDER PERIOD: START-OPEN ORDERS

PART NUMBER	DESCRIPTION	QTY	$/U	TOTAL$	L/T	DELY
002.10	Parallelogram	12	6-	72.00		1
001.10	Blue Disk/motor	1	72.-	72.00		1
009.04	Label, MRP	10	2.-	20.00		1

PURCHASE ORDER

P.O. NUMBER: 2

ORDER PERIOD: START

PART NUMBER	DESCRIPTION	QTY	$/U	TOTAL$	L/T	DELY
003.20	DISK, RED	3	30.-	90.00		2
003.70	motor-~~Dxx~~ remove	4	66	264.00		2
009.03	Label, Model 3	5	2.00	10.00		2

$354.00

PURCHASE ORDER

P.O. NUMBER: 3

ORDER PERIOD: Start

PART NUMBER	DESCRIPTION	QTY	$/U	TOTAL$	L/T	DELY
002.10	Parallelogram	7	6.-	42.00		3
003.30	Disk, orange	3	30.-	90.00		3
003.60	motor; non-remove	8	42	336.00		3
003.70	motor, Removable	5	66	330.00		3
009.05	Staples	1	30-	30.-		3

$828.00

STARTING ON HAND

5	002.10	PARALLELOGRAM, FOLDED
2	009.21	PARALLELOGRAM, BLANK
1	001.10	BLUE DISK/MOTOR ASSY
5	OO1.20	ORNG DISK/MOTOR ASSY
4	001.30	RED DISK/MOTOR ASSY
3	003.20	RED DISK
6	003.30	ORNG DISK
6	003.60	MOTOR, NON-REMOV
3	003.70	MOTOR, REMOV
6	004.10	SHORT WING
18	004.20	LONG WING
20	009.23	WING, LONG, BLANK
2	009.01	LABEL: MOD 1
10	009.02	LABEL: MOD 2
5	009.03	LABEL: MOD 3
8	009.04	LABEL: MRP GAME
30	009.05	STAPLES

MRP Planning

"Explosion" done manually by subjects

MRP GAME BILL OF MATERIAL

PARENT PART NO. 000.10 Starship Model One LOW LEVEL CODE: 0

TYPE OF BILL ( ) REGULAR ( ) PHANTOM ( ) PLANNING

PART NUMBER	DESCRIPTION	QTY
2.10	Folded Parallelogram	1
4.10	Wing, Short Yellow	2
1.10	Blue Disk Motor Assy	1
9.01	Label Mod 1	1
9.04	Label MRP Game	1
9.05	Staples	2

MRP GAME BILL OF MATERIAL

PARENT PART NO. 1.10 Blue Disk Motor Assy LOW LEVEL CODE: 1

TYPE OF BILL ( ) REGULAR ( ) PHANTOM · ( ) PLANNING

PART NUMBER	DESCRIPTION	QTY
3.10	Blue Disk	1
3.60	Motor, Non-Removable	1

MRP GAME BILL OF MATERIAL

PARENT PART NO. 4.10 Wing, Short Yellow LOW LEVEL CODE: 1

TYPE OF BILL ( ) REGULAR ( ) PHANTOM ( ) PLANNING

PART NUMBER	DESCRIPTION	QTY
9.22	Short Wing Blank	1

MRP GAME BILL OF MATERIAL

PARENT PART NO. 210 Folded Parallelogram LOW LEVEL CODE: 1

TYPE OF BILL ( ) REGULAR ( ) PHANTOM ( ) PLANNING

PART NUMBER	DESCRIPTION	QTY
9.21	Parallelogram Blank	1

MRP

ITEM MASTER

ITEM #: 000.10 DESCRIPTION: Starship Model 1

REV: DRAWING #: LOW LEVEL CODE: 0

LEAD TIME: 1 Week SAFETY STOCK: 0 LOT SIZE TECH: L SUPPLY PD: NA

MRP WORKSHEET

	0	1	2	3	4	5	6	7	8	9	10	11	12
REQ #1 Customer	0	1	1	0	0	0	1	1	1				
REQ #2													
REQ #3													
GROSS REQS	0	1	1	0	0	0	1	1	1				

SCHEDULED RECEIPT														
ON HAND	0	0	-1	-2	-2	-2	-2	-3	-4	-5				
PLAN ORDER RECEIPT			1	1	0	0	0	1	1	1				
PLAN ORDER RELEASE		1	1	0	0	0	1	1	1					

© MRP

ITEM MASTER

ITEM #: 000.20 DESCRIPTION: Starship model II

REV: – DRAWING #: – LOW LEVEL CODE: 0

LEAD TIME: 1 week SAFETY STOCK: 0 LOT SIZE TECH: L SUPPLY PD: NA

MRP WORKSHEET

	0	1	2	3	4	5	6	7	8	9	10	11	12
REQ #1 Customer	0	2	3	3	3	3	4	4	4				
REQ #2													
REQ #3													
GROSS REQS	0	2	3	3	3	3	4	4	4				

		0	1	2	3	4	5	6	7	8	9	10	11	12
SCHEDULED RECEIPT														
ON HAND	0	0	-2	-5	-8	-11	-14	-18	-22	-26				
PLAN ORDER RECEIPT		0	2	3	3	3	3	4	4	4				
PLAN ORDER RELEASE		2	3	3	3	3	4	4	4					

MRP ©

ITEM MASTER

ITEM #: 000.30 DESCRIPTION: StarShip Model III

REV: – DRAWING #: – LOW LEVEL CODE: 0

LEAD TIME: 1 week SAFETY STOCK: 0 LOT SIZE TECH: L SUPPLY PD: NA

MRP WORKSHEET

		0	1	2	3	4	5	6	7	8	9	10	11	12
REQ #1	Customer	0	2	2	3	4	4	3	4	3				
REQ #2														
REQ #3														
GROSS REQS		0	2	2	3	4	4	3	4	3				
SCHEDULED RECEIPT														
ON HAND	0	0	-2	-4	-7	-11	-15	-18	-22	-25				
PLAN ORDER RECEIPT		0	2	2	3	4	4	3	4	3				
PLAN ORDER RELEASE		2	2	3	4	4	3	4	3					

ITEM MASTER

ITEM #: 2.10 DESCRIPTION: Folded Parallelogram

REV: – DRAWING #: – LOW LEVEL CODE: 1

LEAD TIME: 1 week SAFETY STOCK: 0 LOT SIZE TECH: L SUPPLY PD: –

MRP WORKSHEET

	0	1	2	3	4	5	6	7	8	9	10	11	12
REQ #1 Model 1	1	1	0	0	0	1	1	1					
REQ #2 Model 2	2	3	3	3	3	4	4	4					
REQ #3 Model 3	2	2	3	4	4	3	4	3					
GROSS REQS	5	6	6	7	7	8	9	8					

		0	1	2	3	4	5	6	7	8	9	10	11	12
SCHEDULED RECEIPT			12		7									
ON HAND	5	0	6	0	0	-7	-15	-24	-32					
PLAN ORDER RECEIPT						7	8	9	8					
PLAN ORDER RELEASE					7	8	9	8						

©

ITEM MASTER

ITEM #: 004.20 DESCRIPTION: Wing, Long Green

REV: - DRAWING #: LOW LEVEL CODE: 1

LEAD TIME: 1 Week SAFETY STOCK: 0 LOT SIZE TECH: L SUPPLY PD: NA

MRP WORKSHEET

	0	1	2	3	4	5	6	7	8	9	10	11	12
REQ #1 Starship mod II	4	6	6	6	6	8	8	8					
REQ #2 Starship mode III	4	4	6	8	8	6	8	6					
REQ #3													
GROSS REQS	8	10	12	14	14	14	16	14					

SCHEDULED RECEIPT													
ON HAND 18	10	0	-12	-26	-40	-54	-70	-84					
PLAN ORDER RECEIPT			12	14	14	14	16	14					
PLAN ORDER RELEASE		12	14	14	14	16	14						

ITEM MASTER

ITEM #: 004.10 DESCRIPTION: Wing Short Yellow

REV: – DRAWING #: – LOW LEVEL CODE: 1

LEAD TIME: 1 Week SAFETY STOCK: – LOT SIZE TECH: L SUPPLY PD: NA

MRP WORKSHEET

	0	1	2	3	4	5	6	7	8	9	10	11	12
REQ #1 Star Ship Model I	2	2	0	0	0	2	2	2					
REQ #2													
REQ #3													
GROSS REQS	2	2	0	0	0	2	2	2					

SCHEDULED RECEIPT													
ON HAND 6	4	2	2	2	2	0	-2	-4					
PLAN ORDER RECEIPT							2	2					
PLAN ORDER RELEASE						2	2						

© MRP

ITEM MASTER

ITEM #: 001.10 DESCRIPTION: Blue Disk Motor Assembly

REV: – DRAWING #: – LOW LEVEL CODE: ~~2~~ 1

LEAD TIME: 1 Week SAFETY STOCK: – LOT SIZE TECH: L SUPPLY PD: NA

MRP WORKSHEET

	0	1	2	3	4	5	6	7	8	9	10	11	12
REQ #1 StarShip Mod I	1	1	0	0	0	1	1	1					
REQ #2													
REQ #3													
GROSS REQS	1	1	0	0	0	1	1	1					

		0	1	2	3	4	5	6	7	8	9	10	11	12
SCHEDULED RECEIPT			1											
ON HAND	1	0	0	0	0	0	-1	-2	-3					
PLAN ORDER RECEIPT							1	1	1					
PLAN ORDER RELEASE						1	1	1						

©

ITEM MASTER

ITEM #: 1.20 DESCRIPTION: Orange Disk Motor Assy

REV: - DRAWING #: - LOW LEVEL CODE: 1

LEAD TIME: 1 week SAFETY STOCK: 0 LOT SIZE TECH: L SUPPLY PD: N/A

MRP WORKSHEET

		0	1	2	3	4	5	6	7	8	9	10	11	12
REQ #1	Starship Model II	2	3	3	3	3	4	4	4					
REQ #2														
REQ #3														
GROSS REQS		2	3	3	3	3	4	4	4					
SCHEDULED RECEIPT														
ON HAND	5	3	0	-3	-6	-9	-13	-17	-21					
PLAN ORDER RECEIPT				3	3	3	4	4	4					
PLAN ORDER RELEASE			3	3	3	4	4	4						

ITEM MASTER

ITEM #: 001.30 DESCRIPTION: Red Disk Motor Assembly
REV: – DRAWING #: – LOW LEVEL CODE: 1
LEAD TIME: 1 Week SAFETY STOCK: 0 LOT SIZE TECH: L SUPPLY PD: NA

MRP WORKSHEET

	0	1	2	3	4	5	6	7	8	9	10	11	12
REQ #1 Starship Model 3	2	2	3	4	4	3	4	3					
REQ #2													
REQ #3													
GROSS REQS	2	2	3	4	4	3	4	3					

SCHEDULED RECEIPT													
ON HAND 4	2	0	-3	-7	-11	-14	-18	-21					
PLAN ORDER RECEIPT			3	4	4	3	4	3					
PLAN ORDER RELEASE		3	4	4	3	4	3						

ITEM MASTER

ITEM #: 009.05 — DESCRIPTION: Staples

REV: – — DRAWING #: – — LOW LEVEL CODE: 1

LEAD TIME: 1 wk — SAFETY STOCK: 0 — LOT SIZE TECH: 30 — SUPPLY PD: NA

MRP WORKSHEET

	0	1	2	3	4	5	6	7	8	9	10	11	12
REQ #1 StarShip Mod I	2	2	0	0	0	2	2	2					
REQ #2 StarShip Mod II	4	6	6	6	6	8	8	8					
REQ #3 StarShip Mod III	4	4	6	8	8	6	8	6					
GROSS REQS	10	12	12	14	14	14	16	14					

SCHEDULED RECEIPT					30									
ON HAND	30	20	8	-4	26	12	-2	-18	-32					
PLAN ORDER RECEIPT				30				30						
PLAN ORDER RELEASE			30				30							

MRP

ITEM MASTER

ITEM #: 009.03 DESCRIPTION: Label Model III
REV: – DRAWING #: – LOW LEVEL CODE: 1
LEAD TIME: 2 WK SAFETY STOCK: 0 LOT SIZE TECH: L SUPPLY PD: NA

MRP WORKSHEET

	0	1	2	3	4	5	6	7	8	9	10	11	12
REQ #1 StarShip Mod III	2	2	3	4	4	3	4	3					
REQ #2													
REQ #3													
GROSS REQS	2	2	3	4	4	3	4	3					

SCHEDULED RECEIPT				5										
ON HAND	5	3	1	3	-1	-5	-8	-12	-15					
PLAN ORDER RECEIPT					1	4	3	4	3					
PLAN ORDER RELEASE			1	4	3	4	3							

© MRP

ITEM MASTER

ITEM #: 009.04 DESCRIPTION: Label MRP Game
REV: – DRAWING #: – LOW LEVEL CODE: 1
LEAD TIME: 2 WK SAFETY STOCK: 0 LOT SIZE TECH: L SUPPLY PD: NA

MRP WORKSHEET

	0	1	2	3	4	5	6	7	8	9	10	11	12
REQ #1 Star Ship Mod I	1	1	0	0	0	1	1	1					
REQ #2 Star Ship Mod II	2	3	3	3	3	4	4	4					
REQ #3 StarShip Mode III	2	2	3	4	4	3	4	3					
GROSS REQS	5	6	6	7	7	8	9	8					

SCHEDULED RECEIPT			10											
ON HAND	8	3	7	1	-6	-13	-21	-30	-38					
PLAN ORDER RECEIPT					6	7	8	9	8					
PLAN ORDER RELEASE			6	7	8	9	8							

MRP

ITEM MASTER

ITEM #: 009.01 DESCRIPTION: Label Model I

REV: - DRAWING #: - LOW LEVEL CODE: 1

LEAD TIME: 2 weeks SAFETY STOCK: 0 LOT SIZE TECH: L SUPPLY PD: NA

MRP WORKSHEET

	0	1	2	3	4	5	6	7	8	9	10	11	12
REQ #1 StarShip Mod I	1	1	0	0	0	1	1	1					
REQ #2													
REQ #3													
GROSS REQS	1	1	0	0	0	1	1	1					

SCHEDULED RECEIPT													
ON HAND 2	1	0	0	0	0	-1	-2	-3					
PLAN ORDER RECEIPT						1	1	1					
PLAN ORDER RELEASE				1	1	1							

MRP

ITEM MASTER

ITEM #: 009.02 DESCRIPTION: Label Model II

REV: – DRAWING #: – LOW LEVEL CODE: 1

LEAD TIME: 2 wk SAFETY STOCK: 0 LOT SIZE TECH: L SUPPLY PD: NA

MRP WORKSHEET

		0	1	2	3	4	5	6	7	8	9	10	11	12
REQ #1 Starship Model II		2	3	3	3	3	4	4	4					
REQ #2														
REQ #3														
GROSS REQS		2	3	3	3	3	4	4	4					
SCHEDULED RECEIPT														
ON HAND	10	8	5	2	-1	-4	-8	-12	-16					
PLAN ORDER RECEIPT					1	3	4	4	4					
PLAN ORDER RELEASE			1	3	4	4	4							

©MRP

ITEM MASTER

ITEM #: 9.21 DESCRIPTION: Parallelogram Blank
REV: – DRAWING #: – LOW LEVEL CODE: 2
LEAD TIME: 1 Week SAFETY STOCK: 0 LOT SIZE TECH: L SUPPLY PD: NA

MRP WORKSHEET

	1	2	3	4	5	6	7	8	9	10	11	12
REQ #1 Folded Para #2.10			7	8	9	8						
REQ #2												
REQ #3												
GROSS REQS			7	8	9	8						

		1	2	3	4	5	6	7	8	9	10	11	12
SCHEDULED RECEIPT													
ON HAND	2			-5	-13	-22	-30						
PLAN ORDER RECEIPT				5	8	9	8						
PLAN ORDER RELEASE			5	8	9	8							

©MRP

ITEM MASTER

ITEM #: 009.22 DESCRIPTION: Wing, Short Blank

REV: – DRAWING #: – LOW LEVEL CODE: 2

LEAD TIME: 1 week SAFETY STOCK: 0 LOT SIZE TECH: L SUPPLY PD: NA

MRP WORKSHEET

		1	2	3	4	5	6	7	8	9	10	11	12
REQ #1 Wing, Short Yellow						2	2						
REQ #2													
REQ #3													
GROSS REQS						2	2						
SCHEDULED RECEIPT													
ON HAND	0					-2	-4						
PLAN ORDER RECEIPT						2	2						
PLAN ORDER RELEASE					2	2							

ITEM MASTER

ITEM #: 009.23 DESCRIPTION: Long Wing Blank

REV: – DRAWING #: – LOW LEVEL CODE: 2

LEAD TIME: 1 Week SAFETY STOCK: 0 LOT SIZE TECH: L SUPPLY PD: NA

MRP WORKSHEET

	0	1	2	3	4	5	6	7	8	9	10	11	12
REQ #1 Long Green Wing		12	14	14	14	16	14						
REQ #2													
REQ #3													
GROSS REQS		12	14	14	14	16	14						

SCHEDULED RECEIPT													
ON HAND 20	20	8	-6	-20	-34	-50	-64						
PLAN ORDER RECEIPT			6	14	14	16	14						
PLAN ORDER RELEASE		6	14	14	16	14							

MRP ©

ITEM MASTER

ITEM #: 3.10 DESCRIPTION: Blue Disk

REV: – DRAWING #: – LOW LEVEL CODE: 2

LEAD TIME: 1 week SAFETY STOCK: 0 LOT SIZE TECH: L SUPPLY PD: NA

MRP WORKSHEET

	1	2	3	4	5	6	7	8	9	10	11	12
REQ #1 Blue Disk Motor Assy				1	1	1						
REQ #2												
REQ #3												
GROSS REQS				1	1	1						

		1	2	3	4	5	6	7	8	9	10	11	12
SCHEDULED RECEIPT													
ON HAND	0				-1	-2	-3						
PLAN ORDER RECEIPT					1	1	1						
PLAN ORDER RELEASE				1	1	1							

© MRP

ITEM MASTER

ITEM # 003.30 DESCRIPTION: Disk, Orange

REV: – DRAWING # – LOW LEVEL CODE: 3

LEAD TIME: 1 Week SAFETY STOCK: 0 LOT SIZE TECH: L SUPPLY PD: NA

MRP WORKSHEET

	0	1	2	3	4	5	6	7	8	9	10	11	12
REQ #1 Orange Disk Motor Assy		3	3	3	4	4	4						
REQ #2													
REQ #3													
GROSS REQS		3	3	3	4	4	4						

		0	1	2	3	4	5	6	7	8	9	10	11	12
SCHEDULED RECEIPT					3									
ON HAND	6	6	3	0	0	-4	-8	-12						
PLAN ORDER RECEIPT						4	4	4						
PLAN ORDER RELEASE					4	4	4							

MRP ©

ITEM MASTER

ITEM # 003.20 DESCRIPTION: Red Disk
REV: – DRAWING # – LOW LEVEL CODE: 2
LEAD TIME: 1 week SAFETY STOCK: 0 LOT SIZE TECH: L SUPPLY PD: –

MRP WORKSHEET

	0	1	2	3	4	5	6	7	8	9	10	11	12
REQ #1 Red Disk Motor Assy		3	4	4	3	4	3						
REQ #2													
REQ #3													
GROSS REQS		3	4	4	3	4	3						

		0	1	2	3	4	5	6	7	8	9	10	11	12
SCHEDULED RECEIPT				3										
ON HAND	3	3	0	-1	-5	-8	-12	-15						
PLAN ORDER RECEIPT				1	4	3	4	3						
PLAN ORDER RELEASE			1	4	3	4	3							

MRP ©

ITEM MASTER

ITEM #: 003.70 DESCRIPTION: Motor / Removable

REV: – DRAWING #: LOW LEVEL CODE:

LEAD TIME: 3 weeks SAFETY STOCK: 0 LOT SIZE TECH: L SUPPLY PD: NA

MRP WORKSHEET

	0	1	2	3	4	5	6	7	8	9	10	11	12
REQ #1 Red Disk motor Assy		3	4	4	3	4	3						
REQ #2													
REQ #3													
GROSS REQS		3	4	4	3	4	3						

		0	1	2	3	4	5	6	7	8	9	10	11	12
SCHEDULED RECEIPT				4	5									
ON HAND	3	3	0	0	1	-2	-6	-9						
PLAN ORDER RECEIPT						2	4	3						
PLAN ORDER RELEASE			2	4	3									

ITEM MASTER

ITEM #: 003.60 DESCRIPTION: Motor / Non Removable
REV: – DRAWING #: – LOW LEVEL CODE: 2
LEAD TIME: 3 Weeks SAFETY STOCK: – LOT SIZE TECH: L SUPPLY PD: NA

MRP WORKSHEET

	0	1	2	3	4	5	6	7	8	9	10	11	12
REQ #1 Blue Disk Motor Assy					1	1	1						
REQ #2 Orange Disk Motor Assy		3	3	3	4	4	4						
REQ #3													
GROSS REQS		3	3	3	5	5	5						
SCHEDULED RECEIPT				8									
ON HAND 6	6	3	0	5	0	-5	-10						
PLAN ORDER RECEIPT						5	5						
PLAN ORDER RELEASE			5	5									

MRP Planning

"Explosion" done by computer using same data as subjects

Run Date: Mar 26, 1993 - 8:11pm Macola Demonstration Company Page 1

MATERIAL REQUIREMENTS BY DATE REPORT

Range: For All Buyer/Analysts Items 000.10 Thru 009.99
For All P&Ic Codes For All Low Level Codes
For All Due Dates For Both Purchased And Manufactured Items
For All Abc Categories

Buyer/ Analyst	Item-Number	Item-Description	Pur/Mfg Primary-Loc	P&Ic Abc	Uom Ll-Cd	Lead-Time Time-Fence	Ord-Pol Ord-Min	Ord-Max Ord-Mult	Avg-Usage Safety-Stk	Stocked Controlled
	000.20	STARSHIP, MODEL 2	M		EA	5	L	.000	.000	Y
			LA		0	0	.000	0	.000	Y

Due Date	Gross Req	Prior Inv	Schd Recpt	Net-Inv	Plan Ord	Ord No	Type	Rel Date	Exception-Situation	Other-Exceptions
04/02/93	2.000	3.000		1.000		2	CO			
04/09/93		1.000		1.000	1.000	000006	CP	04/02/93	J More Needed	
04/09/93	2.000	1.000		1.000-		5	CO			
04/16/93		1.000-		1.000-	3.000	000007	CP	04/09/93	J More Needed	
04/16/93	3.000	1.000-		4.000-		7	CO			
04/23/93		4.000-		4.000-	3.000	000008	CP	04/16/93	J More Needed	
04/23/93	3.000	4.000-		7.000-		9	CO			
04/30/93		7.000-		7.000-	3.000	000009	CP	04/23/93	J More Needed	
04/30/93	3.000	7.000-		10.000-		11	CO			
05/07/93		10.000-		10.000-	4.000	000010	CP	04/30/93	J More Needed	
05/07/93	4.000	10.000-		14.000-		14	CO			
05/14/93		14.000-		14.000-	4.000	000011	CP	05/07/93	J More Needed	
05/14/93	4.000	14.000-		18.000-		17	CO			
05/21/93		18.000-		18.000-	4.000	000012	CP	05/14/93	J More Needed	
05/21/93	4.000	18.000-		22.000-		20	CO			

Buyer/ Analyst	Item-Number	Item-Description	Pur/Mfg Primary-Loc	P&Ic Abc	Uom Ll-Cd	Lead-Time Time-Fence	Ord-Pol Ord-Min	Ord-Max Ord-Mult	Avg-Usage Safety-Stk	Stocked Controlled
	000.30	STARSHIP, MODEL 3	M		EA	5	L	.000	.000	Y
			LA		0	0	.000	0	.000	Y

Due Date	Gross Req	Prior Inv	Schd Recpt	Net-Inv	Plan Ord	Ord No	Type	Rel Date	Exception-Situation	Other-Exceptions
04/02/93		1.000		1.000	1.000	000013	CP	03/26/93	J More Needed	
04/02/93	2.000	1.000		1.000-		3	CO			
04/09/93		1.000-		1.000-	3.000	000014	CP	04/02/93	J More Needed	
04/09/93	3.000	1.000-		4.000-		6	CO			
04/16/93		4.000-		4.000-	3.000	000015	CP	04/09/93	J More Needed	
04/16/93	3.000	4.000-		7.000-		8	CO			
04/23/93		7.000-		7.000-	4.000	000016	CP	04/16/93	J More Needed	
04/23/93	4.000	7.000-		11.000-		10	CO			
04/30/93		11.000-		11.000-	4.000	000017	CP	04/23/93	J More Needed	
04/30/93	4.000	11.000-		15.000-		12	CO			
05/07/93		15.000-		15.000-	3.000	000018	CP	04/30/93	J More Needed	
05/07/93	3.000	15.000-		18.000-		15	CO			
05/14/93		18.000-		18.000-	4.000	000019	CP	05/07/93	J More Needed	
05/14/93	4.000	18.000-		22.000-		18	CO			
05/21/93		22.000-		22.000-	3.000	000020	CP	05/14/93	J More Needed	
05/21/93	3.000	22.000-		25.000-		21	CO			

Buyer/ Analyst	Item-Number	Item-Description	Pur/Mfg Primary-Loc	P&Ic Abc	Uom Ll-Cd	Lead-Time Time-Fence	Ord-Pol Ord-Min	Ord-Max Ord-Mult	Avg-Usage Safety-Stk	Stocked Controlled
	001.10	BLUE DISK/MOTOR ASSY	M		EA	5	L	.000	.000	Y
			LA		1	0	.000	0	.000	Y

Due Date	Gross Req	Prior Inv	Schd Recpt	Net-Inv	Plan Ord	Ord No	Type	Rel Date	Exception-Situation	Other-Exceptions
03/26/93	1.000	1.000		.000		000001	MR			

Run Date: Mar 26, 1993 - 8:11pm Macola Demonstration Company Page 2

MATERIAL REQUIREMENTS BY DATE REPORT

Buyer/ Analyst	Item-Number	Item-Description	Pur/Mfg Primary-Loc	P&lc Abc	Uom Ll-Cd	Lead-Time Time-Fence	Ord-Pol Ord-Min	Ord-Max Ord-Mult	Avg-Usage Safety-Stk	Stocked Controlled
	001.10	BLUE DISK/MOTOR ASSY	M		EA	5	L	.000	.000	Y
			LA		1	0	.000	0	.000	Y

Due Date	Gross Req	Prior Inv	Schd Recpt	Net-Inv	Plan Ord	Ord No	Type	Rel Date	Exception-Situation	Other-Exceptions
04/02/93		.000		.000	1.000	000025	CP	03/26/93	J More Needed	
04/02/93	1.000	.000		1.000-		000002	MR			
04/30/93		1.000-		1.000-	1.000	000026	CP	04/23/93	J More Needed	
04/30/93	1.000	1.000-		2.000-		000003	MR			
05/07/93		2.000-		2.000-	1.000	000027	CP	04/30/93	J More Needed	
05/07/93	1.000	2.000-		3.000-		000004	MR			
05/14/93		3.000-		3.000-	1.000	000028	CP	05/07/93	J More Needed	
05/14/93	1.000	3.000-		4.000-		000005	MR			
05/25/93		4.000-		4.000-	40.000	000029	CP	05/18/93	J More Needed	
05/25/93	40.000	4.000-		44.000-		000022	MR			

Buyer/ Analyst	Item-Number	Item-Description	Pur/Mfg Primary-Loc	P&lc Abc	Uom Ll-Cd	Lead-Time Time-Fence	Ord-Pol Ord-Min	Ord-Max Ord-Mult	Avg-Usage Safety-Stk	Stocked Controlled
	001.20	Orange Disk/Motor Assembly	M		EA	5	L	.000	.000	Y
			LA		1	0	.000	0	.000	Y

Due Date	Gross Req	Prior Inv	Schd Recpt	Net-Inv	Plan Ord	Ord No	Type	Rel Date	Exception-Situation	Other-Exceptions
04/02/93	1.000	5.000		4.000		000006	MR			
04/09/93	3.000	4.000		1.000		000007	MR			
04/16/93		1.000		1.000	2.000	000030	CP	04/09/93	J More Needed	
04/16/93	3.000	1.000		2.000-		000008	MR			
04/23/93		2.000-		2.000-	3.000	000031	CP	04/16/93	J More Needed	
04/23/93	3.000	2.000-		5.000-		000009	MR			
04/30/93		5.000-		5.000-	4.000	000032	CP	04/23/93	J More Needed	
04/30/93	4.000	5.000-		9.000-		000010	MR			
05/07/93		9.000-		9.000-	4.000	000033	CP	04/30/93	J More Needed	
05/07/93	4.000	9.000-		13.000-		000011	MR			
05/14/93		13.000-		13.000-	4.000	000034	CP	05/07/93	J More Needed	
05/14/93	4.000	13.000-		17.000-		000012	MR			
05/25/93		17.000-		17.000-	48.000	000035	CP	05/18/93	J More Needed	
05/25/93	48.000	17.000-		65.000-		000023	MR			

Buyer/ Analyst	Item-Number	Item-Description	Pur/Mfg Primary-Loc	P&lc Abc	Uom Ll-Cd	Lead-Time Time-Fence	Ord-Pol Ord-Min	Ord-Max Ord-Mult	Avg-Usage Safety-Stk	Stocked Controlled
	002.10	PARALLELOGRAM, WHITE	M		EA	5	L	.000	.000	Y
			LA		1	0	.000	0	.000	Y

Due Date	Gross Req	Prior Inv	Schd Recpt	Net-Inv	Plan Ord	Ord No	Type	Rel Date	Exception-Situation	Other-Exceptions
03/26/93	1.000	5.000		4.000		000001	MR			
03/26/93	1.000	4.000		3.000		000013	MR			
04/02/93		3.000		3.000	2.000	000036	CP	03/26/93	J More Needed	
04/02/93	1.000	3.000		2.000		000002	MR			
04/02/93	1.000	2.000		1.000		000006	MR			
04/02/93	3.000	1.000		2.000-		000014	MR			
04/09/93		2.000-		2.000-	6.000	000037	CP	04/02/93	J More Needed	
04/09/93	3.000	2.000-		5.000-		000007	MR			
04/09/93	3.000	5.000-		8.000-		000015	MR			
04/16/93		8.000-		8.000-	7.000	000038	CP	04/09/93	J More Needed	
04/16/93	3.000	8.000-		11.000-		000008	MR			
04/16/93	4.000	11.000-		15.000-		000016	MR			
04/23/93		15.000-		15.000-	7.000	000039	CP	04/16/93	J More Needed	

M A T E R I A L R E Q U I R E M E N T S B Y D A T E R E P O R T

Buyer/ Analyst	Item-Number	Item-Description	Pur/Mfg Primary-Loc	P&Ic Abc	Uom Ll-Cd	Lead-Time Time-Fence	Ord-Pol Ord-Min	Ord-Max Ord-Mult	Avg-Usage Safety-Stk	Stocked Controlled
	002.10	PARALLELOGRAM, WHITE	M		EA	5	L	.000	.000	Y
			LA		1	0	.000	0	.000	Y

Due Date	Gross Req	Prior Inv	Schd Recpt	Net-Inv	Plan Ord	Ord No	Type	Rel Date	Exception-Situation	Other-Exceptions
04/23/93	3.000	15.000-		18.000-		000009	MR			
04/23/93	4.000	18.000-		22.000-		000017	MR			
04/30/93		22.000-		22.000-	8.000	000040	CP	04/23/93	J More Needed	
04/30/93	1.000	22.000-		23.000-		000003	MR			
04/30/93	4.000	23.000-		27.000-		000010	MR			
04/30/93	3.000	27.000-		30.000-		000018	MR			
05/07/93		30.000-		30.000-	9.000	000041	CP	04/30/93	J More Needed	
05/07/93	1.000	30.000-		31.000-		000004	MR			
05/07/93	4.000	31.000-		35.000-		000011	MR			
05/07/93	4.000	35.000-		39.000-		000019	MR			
05/14/93		39.000-		39.000-	8.000	000042	CP	05/07/93	J More Needed	
05/14/93	1.000	39.000-		40.000-		000005	MR			
05/14/93	4.000	40.000-		44.000-		000012	MR			
05/14/93	3.000	44.000-		47.000-		000020	MR			
05/25/93		47.000-		47.000-	14.400	000043	CP	05/18/93	J More Needed	
05/25/93	9.600	47.000-		56.600-		000023	MR			
05/25/93	4.800	56.600-		61.400-		000024	MR			

Buyer/ Analyst	Item-Number	Item-Description	Pur/Mfg Primary-Loc	P&Ic Abc	Uom Ll-Cd	Lead-Time Time-Fence	Ord-Pol Ord-Min	Ord-Max Ord-Mult	Avg-Usage Safety-Stk	Stocked Controlled
	003.10	DISK, BLUE	P	RM	EA	5	L	.000	.000	Y
			LA		2	0	.000	0	.000	Y

Due Date	Gross Req	Prior Inv	Schd Recpt	Net-Inv	Plan Ord	Ord No	Type	Rel Date	Exception-Situation	Other-Exceptions
03/26/93		.000		.000	1.000	000078	CP	03/19/93	J More Needed	
03/26/93	1.000	.000		1.000-		000025	MR			
04/23/93		1.000-		1.000-	1.000	000079	CP	04/16/93	J More Needed	
04/23/93	1.000	1.000-		2.000-		000026	MR			
04/30/93		2.000-		2.000-	1.000	000080	CP	04/23/93	J More Needed	
04/30/93	1.000	2.000-		3.000-		000027	MR			
05/07/93		3.000-		3.000-	1.000	000081	CP	04/30/93	J More Needed	
05/07/93	1.000	3.000-		4.000-		000028	MR			
05/18/93		4.000-		4.000-	40.000	000082	CP	05/11/93	J More Needed	
05/18/93	40.000	4.000-		44.000-		000029	MR			

Buyer/ Analyst	Item-Number	Item-Description	Pur/Mfg Primary-Loc	P&Ic Abc	Uom Ll-Cd	Lead-Time Time-Fence	Ord-Pol Ord-Min	Ord-Max Ord-Mult	Avg-Usage Safety-Stk	Stocked Controlled
	003.20	Red Disk	P	RM	EA	5	L	.000	.000	Y
			LA		2	0	.000	0	.000	Y

Due Date	Gross Req	Prior Inv	Schd Recpt	Net-Inv	Plan Ord	Ord No	Type	Rel Date	Exception-Situation	Other-Exceptions
05/25/93		3.000		3.000	1.800	000083	CP	05/18/93	J More Needed	
05/25/93	4.800	3.000		1.800-		000024	MR			

Buyer/ Analyst	Item-Number	Item-Description	Pur/Mfg Primary-Loc	P&Ic Abc	Uom Ll-Cd	Lead-Time Time-Fence	Ord-Pol Ord-Min	Ord-Max Ord-Mult	Avg-Usage Safety-Stk	Stocked Controlled
	003.30	Orange Disk	P	RM	EA	5	L	.000	.000	Y
			LA		2	0	.000	0	.000	Y

Due Date	Gross Req	Prior Inv	Schd Recpt	Net-Inv	Plan Ord	Ord No	Type	Rel Date	Exception-Situation	Other-Exceptions
04/09/93	2.000	6.000		4.000		000030	MR			
04/16/93	3.000	4.000		1.000		000031	MR			

Run Date: Mar 26, 1993 - 8:12pm   Macola Demonstration Company   Page 4

MATERIAL REQUIREMENTS BY DATE REPORT

Buyer/ Analyst	Item-Number	Item-Description	Pur/Mfg Primary-Loc	P&Ic Abc	Uom Li-Cd	Lead-Time Time-Fence	Ord-Pol Ord-Min	Ord-Max Ord-Mult	Avg-Usage Safety-Stk	Stocked Controlled
	003.30	Orange Disk	P	RM	EA	5	L	.000	.000	Y
			LA		2	0	.000	0	.000	Y

Due Date	Gross Req	Prior Inv	Schd Recpt	Net-Inv	Plan Ord	Ord No	Type	Rel Date	Exception-Situation	Other-Exceptions
04/23/93		1.000		1.000	3.000	000084	CP	04/16/93	J More Needed	
04/23/93	4.000	1.000		3.000-		000032	MR			
04/30/93		3.000-		3.000-	4.000	000085	CP	04/23/93	J More Needed	
04/30/93	4.000	3.000-		7.000-		000033	MR			
05/07/93		7.000-		7.000-	4.000	000086	CP	04/30/93	J More Needed	
05/07/93	4.000	7.000-		11.000-		000034	MR			
05/18/93		11.000-		11.000-	48.000	000087	CP	05/11/93	J More Needed	
05/18/93	48.000	11.000-		59.000-		000035	MR			

Buyer/ Analyst	Item-Number	Item-Description	Pur/Mfg Primary-Loc	P&Ic Abc	Uom Li-Cd	Lead-Time Time-Fence	Ord-Pol Ord-Min	Ord-Max Ord-Mult	Avg-Usage Safety-Stk	Stocked Controlled
	003.60	MOTOR, NON-REMOVABLE	P	RM	EA	15	L	.000	.000	Y
			LA		2	0	.000	0	.000	Y

Due Date	Gross Req	Prior Inv	Schd Recpt	Net-Inv	Plan Ord	Ord No	Type	Rel Date	Exception-Situation	Other-Exceptions
03/26/93	1.000	6.000		5.000		000025	MR			
04/09/93	2.000	5.000		3.000		000030	MR			
04/16/93	3.000	3.000		.000		000031	MR			
04/23/93		.000		.000	5.000	000088	CP	04/02/93	J More Needed	
04/23/93	1.000	.000		1.000-		000026	MR			
04/23/93	4.000	1.000-		5.000-		000032	MR			
04/30/93		5.000-		5.000-	5.000	000089	CP	04/09/93	J More Needed	
04/30/93	1.000	5.000-		6.000-		000027	MR			
04/30/93	4.000	6.000-		10.000-		000033	MR			
05/07/93		10.000-		10.000-	5.000	000090	CP	04/16/93	J More Needed	
05/07/93	1.000	10.000-		11.000-		000028	MR			
05/07/93	4.000	11.000-		15.000-		000034	MR			
05/18/93		15.000-		15.000-	88.000	000091	CP	04/27/93	J More Needed	
05/18/93	40.000	15.000-		55.000-		000029	MR			
05/18/93	48.000	55.000-		103.000-		000035	MR			

Buyer/ Analyst	Item-Number	Item-Description	Pur/Mfg Primary-Loc	P&Ic Abc	Uom Li-Cd	Lead-Time Time-Fence	Ord-Pol Ord-Min	Ord-Max Ord-Mult	Avg-Usage Safety-Stk	Stocked Controlled
	003.70	Motor, Removable	P	RM	EA	15	L	.000	.000	Y
			LA		2	0	.000	0	.000	Y

Due Date	Gross Req	Prior Inv	Schd Recpt	Net-Inv	Plan Ord	Ord No	Type	Rel Date	Exception-Situation	Other-Exceptions
05/25/93		3.000		3.000	4.200	000092	CP	05/04/93	J More Needed	
05/25/93	7.200	3.000		4.200-		000024	MR			

Buyer/ Analyst	Item-Number	Item-Description	Pur/Mfg Primary-Loc	P&Ic Abc	Uom Li-Cd	Lead-Time Time-Fence	Ord-Pol Ord-Min	Ord-Max Ord-Mult	Avg-Usage Safety-Stk	Stocked Controlled
	004.10	Wing, short yellow	M		EA	5	L	.000	.000	Y
			LA		1	0	.000	0	.000	Y

Due Date	Gross Req	Prior Inv	Schd Recpt	Net-Inv	Plan Ord	Ord No	Type	Rel Date	Exception-Situation	Other-Exceptions
03/26/93	2.000	6.000		4.000		000001	MR			
04/02/93	2.000	4.000		2.000		000002	MR			
04/30/93	2.000	2.000		.000		000003	MR			
05/07/93		.000		.000	2.000	000044	CP	04/30/93	J More Needed	
05/07/93	2.000	.000		2.000-		000004	MR			
05/14/93		2.000-		2.000-	2.000	000045	CP	05/07/93	J More Needed	

MATERIAL REQUIREMENTS BY DATE REPORT

Buyer/ Analyst	Item-Number	Item-Description	Pur/Mfg Primary-Loc	P&Ic Abc	Uom Lt-Cd	Lead-Time Time-Fence	Ord-Pol Ord-Min	Ord-Max Ord-Mult	Avg-Usage Safety-Stk	Stocked Controlled
	004.10	Wing, short yellow	M		EA	5	L	.000	.000	Y
			LA		1	0	.000	0	.000	Y

Due Date	Gross Req	Prior Inv	Schd Recpt	Net-Inv	Plan Ord	Ord No	Type	Rel Date	Exception-Situation	Other-Exceptions
05/14/93	2.000	2.000-		4.000-		000005	MR			
05/25/93		4.000-		4.000-	80.000	000046	CP	05/18/93	J More Needed	
05/25/93	80.000	4.000-		84.000-		000022	MR			

Buyer/ Analyst	Item-Number	Item-Description	Pur/Mfg Primary-Loc	P&Ic Abc	Uom Lt-Cd	Lead-Time Time-Fence	Ord-Pol Ord-Min	Ord-Max Ord-Mult	Avg-Usage Safety-Stk	Stocked Controlled
	004.20	Wing, Long Green	M		EA	5	L	.000	.000	Y
			LA		1	0	.000	0	.000	Y

Due Date	Gross Req	Prior Inv	Schd Recpt	Net-Inv	Plan Ord	Ord No	Type	Rel Date	Exception-Situation	Other-Exceptions
03/26/93	2.000	18.000		16.000		000013	MR			
04/02/93	2.000	16.000		14.000		000006	MR			
04/02/93	6.000	14.000		8.000		000014	MR			
04/09/93		8.000		8.000	4.000	000047	CP	04/02/93	J More Needed	
04/09/93	6.000	8.000		2.000		000007	MR			
04/09/93	6.000	2.000		4.000-		000015	MR			
04/16/93		4.000-		4.000-	14.000	000048	CP	04/09/93	J More Needed	
04/16/93	6.000	4.000-		10.000-		000008	MR			
04/16/93	8.000	10.000-		18.000-		000016	MR			
04/23/93		18.000-		18.000-	14.000	000049	CP	04/16/93	J More Needed	
04/23/93	6.000	18.000-		24.000-		000009	MR			
04/23/93	8.000	24.000-		32.000-		000017	MR			
04/30/93		32.000-		32.000-	14.000	000050	CP	04/23/93	J More Needed	
04/30/93	8.000	32.000-		40.000-		000010	MR			
04/30/93	6.000	40.000-		46.000-		000018	MR			
05/07/93		46.000-		46.000-	16.000	000051	CP	04/30/93	J More Needed	
05/07/93	8.000	46.000-		54.000-		000011	MR			
05/07/93	8.000	54.000-		62.000-		000019	MR			
05/14/93		62.000-		62.000-	14.000	000052	CP	05/07/93	J More Needed	
05/14/93	8.000	62.000-		70.000-		000012	MR			
05/14/93	6.000	70.000-		76.000-		000020	MR			
05/25/93		76.000-		76.000-	79.200	000053	CP	05/18/93	J More Needed	
05/25/93	50.400	76.000-		126.400-		000023	MR			
05/25/93	28.800	126.400-		155.200-		000024	MR			

Buyer/ Analyst	Item-Number	Item-Description	Pur/Mfg Primary-Loc	P&Ic Abc	Uom Lt-Cd	Lead-Time Time-Fence	Ord-Pol Ord-Min	Ord-Max Ord-Mult	Avg-Usage Safety-Stk	Stocked Controlled
	009.01	Label: Model 1	P	RM	EA	10	L	.000	.000	Y
			LA		1	0	.000	0	.000	Y

Due Date	Gross Req	Prior Inv	Schd Recpt	Net-Inv	Plan Ord	Ord No	Type	Rel Date	Exception-Situation	Other-Exceptions
03/26/93	1.000	2.000		1.000		000001	MR			
04/02/93	1.000	1.000		.000		000002	MR			
04/30/93		.000		.000	1.000	000054	CP	04/16/93	J More Needed	
04/30/93	1.000	.000		1.000-		000003	MR			
05/07/93		1.000-		1.000-	1.000	000055	CP	04/23/93	J More Needed	
05/07/93	1.000	1.000-		2.000-		000004	MR			
05/14/93		2.000-		2.000-	1.000	000056	CP	04/30/93	J More Needed	
05/14/93	1.000	2.000-		3.000-		000005	MR			
05/25/93		3.000-		3.000-	40.000	000057	CP	05/11/93	J More Needed	
05/25/93	40.000	3.000-		43.000-		000022	MR			

Run Date: Mar 26, 1993 - 8:12pm Macola Demonstration Company Page 6

MATERIAL REQUIREMENTS BY DATE REPORT

Buyer/ Analyst	Item-Number	Item-Description	Pur/Mfg Primary-Loc	P&Ic Abc	Uom LL-Cd	Lead-Time Time-Fence	Ord-Pol Ord-Min	Ord-Max Ord-Mult	Avg-Usage Safety-Stk	Stocked Controlled
	009.02	Label: Model 2	P	RM	EA	10	L	.000	.000	Y
			LA		1	0	.000	0	.000	Y

Due Date	Gross Req	Prior Inv	Schd Recpt	Net-Inv	Plan Ord	Ord No	Type	Rel Date	Exception-Situation	Other-Exceptions
04/02/93	1.000	10.000		9.000		000006	MR			
04/09/93	3.000	9.000		6.000		000007	MR			
04/16/93	3.000	6.000		3.000		000008	MR			
04/23/93	3.000	3.000		.000		000009	MR			
04/30/93		.000		.000	4.000	000058	CP	04/16/93	J More Needed	
04/30/93	4.000	.000		4.000-		000010	MR			
05/07/93		4.000-		4.000-	4.000	000059	CP	04/23/93	J More Needed	
05/07/93	4.000	4.000-		8.000-		000011	MR			
05/14/93		8.000-		8.000-	4.000	000060	CP	04/30/93	J More Needed	
05/14/93	4.000	8.000-		12.000-		000012	MR			
05/25/93		12.000-		12.000-	48.000	000061	CP	05/11/93	J More Needed	
05/25/93	48.000	12.000-		60.000-		000023	MR			

Buyer/ Analyst	Item-Number	Item-Description	Pur/Mfg Primary-Loc	P&Ic Abc	Uom LL-Cd	Lead-Time Time-Fence	Ord-Pol Ord-Min	Ord-Max Ord-Mult	Avg-Usage Safety-Stk	Stocked Controlled
	009.03	Label: Model 3	P	RM	EA	10	L	.000	.000	Y
			LA		1	0	.000	0	.000	Y

Due Date	Gross Req	Prior Inv	Schd Recpt	Net-Inv	Plan Ord	Ord No	Type	Rel Date	Exception-Situation	Other-Exceptions
03/26/93	1.000	5.000		4.000		000013	MR			
04/02/93	3.000	4.000		1.000		000014	MR			
04/09/93		1.000		1.000	2.000	000062	CP	03/26/93	J More Needed	
04/09/93	3.000	1.000		2.000-		000015	MR			
04/16/93		2.000-		2.000-	4.000	000063	CP	04/02/93	J More Needed	
04/16/93	4.000	2.000-		6.000-		000016	MR			
04/23/93		6.000-		6.000-	4.000	000064	CP	04/09/93	J More Needed	
04/23/93	4.000	6.000-		10.000-		000017	MR			
04/30/93		10.000-		10.000-	3.000	000065	CP	04/16/93	J More Needed	
04/30/93	3.000	10.000-		13.000-		000018	MR			
05/07/93		13.000-		13.000-	4.000	000066	CP	04/23/93	J More Needed	
05/07/93	4.000	13.000-		17.000-		000019	MR			
05/14/93		17.000-		17.000-	3.000	000067	CP	04/30/93	J More Needed	
05/14/93	3.000	17.000-		20.000-		000020	MR			
05/25/93		20.000-		20.000-	24.000	000068	CP	05/11/93	J More Needed	
05/25/93	24.000	20.000-		44.000-		000024	MR			

Buyer/ Analyst	Item-Number	Item-Description	Pur/Mfg Primary-Loc	P&Ic Abc	Uom LL-Cd	Lead-Time Time-Fence	Ord-Pol Ord-Min	Ord-Max Ord-Mult	Avg-Usage Safety-Stk	Stocked Controlled
	009.04	Label: MRP Game	P	RM	EA	10	L	.000	.000	Y
			LA		1	0	.000	0	.000	Y

Due Date	Gross Req	Prior Inv	Schd Recpt	Net-Inv	Plan Ord	Ord No	Type	Rel Date	Exception-Situation	Other-Exceptions
03/26/93	1.000	8.000		7.000		000001	MR			
03/26/93	1.000	7.000		6.000		000013	MR			
04/02/93	1.000	6.000		5.000		000002	MR			
04/02/93	1.000	5.000		4.000		000006	MR			
04/02/93	3.000	4.000		1.000		000014	MR			
04/09/93		1.000		1.000	5.000	000069	CP	03/26/93	J More Needed	
04/09/93	3.000	1.000		2.000-		000007	MR			
04/09/93	3.000	2.000-		5.000-		000015	MR			
04/16/93		5.000-		5.000-	7.000	000070	CP	04/02/93	J More Needed	

MATERIAL REQUIREMENTS BY DATE REPORT

Buyer/ Analyst	Item-Number	Item-Description	Pur/Mfg Primary-Loc	P&lc Abc	Uom Lt-Cd	Lead-Time Time-Fence	Ord-Pol Ord-Min	Ord-Max Ord-Mult	Avg-Usage Safety-Stk	Stocked Controlled
	009.04	Label: MRP Game	P	RM	EA	10	L	.000	.000	Y
			LA		1	0	.000	0	.000	Y

Due Date	Gross Req	Prior Inv	Schd Recpt	Net-Inv	Plan Ord	Ord No	Type	Rel Date	Exception-Situation	Other-Exceptions
04/16/93	3.000	5.000-		8.000-		000008	MR			
04/16/93	4.000	8.000-		12.000-		000016	MR			
04/23/93		12.000-		12.000-	7.000	000071	CP	04/09/93	J More Needed	
04/23/93	3.000	12.000-		15.000-		000009	MR			
04/23/93	4.000	15.000-		19.000-		000017	MR			
04/30/93		19.000-		19.000-	8.000	000072	CP	04/16/93	J More Needed	
04/30/93	1.000	19.000-		20.000-		000003	MR			
04/30/93	4.000	20.000-		24.000-		000010	MR			
04/30/93	3.000	24.000-		27.000-		000018	MR			
05/07/93		27.000-		27.000-	9.000	000073	CP	04/23/93	J More Needed	
05/07/93	1.000	27.000-		28.000-		000004	MR			
05/07/93	4.000	28.000-		32.000-		000011	MR			
05/07/93	4.000	32.000-		36.000-		000019	MR			
05/14/93		36.000-		36.000-	8.000	000074	CP	04/30/93	J More Needed	
05/14/93	1.000	36.000-		37.000-		000005	MR			
05/14/93	4.000	37.000-		41.000-		000012	MR			
05/14/93	3.000	41.000-		44.000-		000020	MR			
05/25/93		44.000-		44.000-	47.200	000075	CP	05/11/93	J More Needed	
05/25/93	40.000	44.000-		84.000-		000022	MR			
05/25/93	2.400	84.000-		86.400-		000023	MR			
05/25/93	4.800	86.400-		91.200-		000024	MR			

Buyer/ Analyst	Item-Number	Item-Description	Pur/Mfg Primary-Loc	P&lc Abc	Uom Lt-Cd	Lead-Time Time-Fence	Ord-Pol Ord-Min	Ord-Max Ord-Mult	Avg-Usage Safety-Stk	Stocked Controlled
	009.21	Parallelogram Blank	P	RM	EA	5	L	.000	.000	Y
			LA		2	0	.000	0	.000	Y

Due Date	Gross Req	Prior Inv	Schd Recpt	Net-Inv	Plan Ord	Ord No	Type	Rel Date	Exception-Situation	Other-Exceptions
03/26/93	2.000	2.000		.000		000036	MR			
04/02/93		.000		.000	6.000	000093	CP	03/26/93	J More Needed	
04/02/93	6.000	.000		6.000-		000037	MR			
04/09/93		6.000-		6.000-	7.000	000094	CP	04/02/93	J More Needed	
04/09/93	7.000	6.000-		13.000-		000038	MR			
04/16/93		13.000-		13.000-	7.000	000095	CP	04/09/93	J More Needed	
04/16/93	7.000	13.000-		20.000-		000039	MR			
04/23/93		20.000-		20.000-	8.000	000096	CP	04/16/93	J More Needed	
04/23/93	8.000	20.000-		28.000-		000040	MR			
04/30/93		28.000-		28.000-	9.000	000097	CP	04/23/93	J More Needed	
04/30/93	9.000	28.000-		37.000-		000041	MR			
05/07/93		37.000-		37.000-	8.000	000098	CP	04/30/93	J More Needed	
05/07/93	8.000	37.000-		45.000-		000042	MR			
05/18/93		45.000-		45.000-	14.400	000099	CP	05/11/93	J More Needed	
05/18/93	14.400	45.000-		59.400-		000043	MR			

Buyer/ Analyst	Item-Number	Item-Description	Pur/Mfg Primary-Loc	P&lc Abc	Uom Lt-Cd	Lead-Time Time-Fence	Ord-Pol Ord-Min	Ord-Max Ord-Mult	Avg-Usage Safety-Stk	Stocked Controlled
	009.22	Wing, short blank	P	RM	EA	5	L	.000	.000	Y
			LA		2	0	.000	0	.000	Y

Due Date	Gross Req	Prior Inv	Schd Recpt	Net-Inv	Plan Ord	Ord No	Type	Rel Date	Exception-Situation	Other-Exceptions
04/30/93		.000		.000	2.000	000100	CP	04/23/93	J More Needed	

Run Date: Mar 26, 1993 - 8:12pm Macola Demonstration Company Page 8

MATERIAL REQUIREMENTS BY DATE REPORT

Buyer/ Analyst	Item-Number	Item-Description	Pur/Mfg Primary-Loc	P&lc Abc	Uom Ll-Cd	Lead-Time Time-Fence	Ord-Pol Ord-Min	Ord-Max Ord-Mult	Avg-Usage Safety-Stk	Stocked Controlled
	009.22	Wing, short blank	P	RM	EA	5	L	.000	.000	Y
			LA		2	0	.000	0	.000	Y

Due Date	Gross Req	Prior Inv	Schd Recpt	Net-Inv	Plan Ord	Ord No	Type	Rel Date	Exception-Situation	Other-Exceptions
04/30/93	2.000	.000		2.000-		000044	MR			
05/07/93		2.000-		2.000-	2.000	000101	CP	04/30/93	J More Needed	
05/07/93	2.000	2.000-		4.000-		000045	MR			
05/18/93		4.000-		4.000-	80.000	000102	CP	05/11/93	J More Needed	
05/18/93	80.000	4.000-		84.000-		000046	MR			

Buyer/ Analyst	Item-Number	Item-Description	Pur/Mfg Primary-Loc	P&lc Abc	Uom Ll-Cd	Lead-Time Time-Fence	Ord-Pol Ord-Min	Ord-Max Ord-Mult	Avg-Usage Safety-Stk	Stocked Controlled
	009.23	Wing, Long Blank	P	RM	EA	5	L	.000	.000	Y
			LA		2	0	.000	0	.000	Y

Due Date	Gross Req	Prior Inv	Schd Recpt	Net-Inv	Plan Ord	Ord No	Type	Rel Date	Exception-Situation	Other-Exceptions
04/02/93	4.000	20.000		16.000		000047	MR			
04/09/93	14.000	16.000		2.000		000048	MR			
04/16/93		2.000		2.000	12.000	000103	CP	04/09/93	J More Needed	
04/16/93	14.000	2.000		12.000-		000049	MR			
04/23/93		12.000-		12.000-	14.000	000104	CP	04/16/93	J More Needed	
04/23/93	14.000	12.000-		26.000-		000050	MR			
04/30/93		26.000-		26.000-	16.000	000105	CP	04/23/93	J More Needed	
04/30/93	16.000	26.000-		42.000-		000051	MR			
05/07/93		42.000-		42.000-	14.000	000106	CP	04/30/93	J More Needed	
05/07/93	14.000	42.000-		56.000-		000052	MR			
05/18/93		56.000-		56.000-	79.200	000107	CP	05/11/93	J More Needed	
05/18/93	79.200	56.000-		135.200-		000053	MR			

Buyer/ Analyst	Item-Number	Item-Description	Pur/Mfg Primary-Loc	P&lc Abc	Uom Ll-Cd	Lead-Time Time-Fence	Ord-Pol Ord-Min	Ord-Max Ord-Mult	Avg-Usage Safety-Stk	Stocked Controlled
1	000.10	STARSHIP, MODEL 1	M	FC	EA	5	L	.000	.000	Y
Larry Haverhill			LA	C	0	0	.000	0	.000	Y

Due Date	Gross Req	Prior Inv	Schd Recpt	Net-Inv	Plan Ord	Ord No	Type	Rel Date	Exception-Situation	Other-Exceptions
04/02/93		.000		.000	1.000	000001	CP	03/26/93	J More Needed	
04/02/93	1.000	.000		1.000-		1	CO			
04/09/93		1.000-		1.000-	1.000	000002	CP	04/02/93	J More Needed	
04/09/93	1.000	1.000-		2.000-		4	CO			
05/07/93		2.000-		2.000-	1.000	000003	CP	04/30/93	J More Needed	
05/07/93	1.000	2.000-		3.000-		13	CO			
05/14/93		3.000-		3.000-	1.000	000004	CP	05/07/93	J More Needed	
05/14/93	1.000	3.000-		4.000-		16	CO			
05/21/93		4.000-		4.000-	1.000	000005	CP	05/14/93	J More Needed	
05/21/93	1.000	4.000-		5.000-		19	CO			

Run Date: May 17, 1993 - 1:55pm Macola Demonstration Company Page 1

MRP PLANNED ORDERS REPORT

Range: For All Buyer/Analysts — Items 000.10 Thru 009.99
For All Release Dates — For All P&lc Codes
Low Level Codes 0 Thru 11 — For Manufactured Items Only
For All Abc Categories — For Both Computer And Firm Planned Orders
For Stocked Items Only

Buyer/ Analyst	Item-Number / Item-Description	Pur/Mfg	Ms-Itm / Uom	P&lc / Llc	Abc / Ord-Pol	Ld-Time / Tim-Fnc	Avg-Cost / Min	Max / Mult	Avg-Usage / Safty-Stk	Ord Typ	Req Rel-Date	Ord-Qty	Due-Date
* Not On File *													
	000.20	M	Y			5	88.0000	.000	.000	CP	03/26/93	2.000	04/02/93
	STARSHIP, MODEL 2		EA	0	L	0	.000	0	.000	CP	04/02/93	4.000	04/09/93
										CP	04/09/93	6.000	04/16/93
										CP	04/16/93	6.000	04/23/93
										CP	04/23/93	6.000	04/30/93
										CP	04/30/93	7.000	05/07/93
										CP	05/07/93	8.000	05/14/93
										CP	05/14/93	8.000	05/21/93
										CP	05/21/93	4.000	05/28/93
	000.30	M	Y			5	112.0000	.000	.000	CP	03/26/93	2.000	04/02/93
	STARSHIP, MODEL 3		EA	0	L	0	.000	0	.000	CP	04/02/93	5.000	04/09/93
										CP	04/09/93	5.000	04/16/93
										CP	04/16/93	7.000	04/23/93
										CP	04/23/93	8.000	04/30/93
										CP	04/30/93	7.000	05/07/93
										CP	05/07/93	7.000	05/14/93
										CP	05/14/93	7.000	05/21/93
										CP	05/21/93	3.000	05/28/93
	001.10	M	N			5	72.0000	.000	.000	CP	03/24/93	8.000	03/31/93
	BLUE DISK/MOTOR ASSY		EA	1	L	0	.000	0	.000	CP	03/26/93	2.000	04/02/93
										CP	04/02/93	1.000	04/09/93
										CP	04/23/93	1.000	04/30/93
										CP	04/30/93	2.000	05/07/93
										CP	05/07/93	2.000	05/14/93
										CP	05/14/93	1.000	05/21/93
										CP	05/25/93	8.000	06/01/93
										CP	06/02/93	8.000	06/09/93
	001.20	M	N			5	72.0000	.000	.000	CP	03/26/93	1.000	04/02/93
	Orange Disk/Motor Assembly		EA	1	L	0	.000	0	.000	CP	03/31/93	12.000	04/07/93
										CP	04/02/93	6.000	04/09/93
										CP	04/09/93	6.000	04/16/93
										CP	04/16/93	6.000	04/23/93
										CP	04/23/93	7.000	04/30/93
										CP	04/30/93	8.000	05/07/93
										CP	05/07/93	8.000	05/14/93
										CP	05/14/93	4.000	05/21/93
	002.10	M	N			5	4.0000	.000	.000	CP	03/26/93	11.000	04/02/93
	PARALLELOGRAM, WHITE		EA	1	L	0	.000	0	.000	CP	03/31/93	2.400	04/07/93
										CP	04/02/93	12.000	04/09/93
										CP	04/09/93	13.000	04/16/93
										CP	04/16/93	14.000	04/23/93

M R P P L A N N E D O R D E R S R E P O R T

Buyer/ Analyst	Item-Number Item-Description	Pur/Mfg	Ms-Itm Uom	P&lc Llc	Abc Ord-Pol	Ld-Time Tim-Fnc	Avg-Cost Min	Max Mult	Avg-Usage Safty-Stk	Ord Typ	Req Rel-Date	Ord-Qty	Due-Date
	002.10	M	N			5	4.0000	.000	.000	CP	04/23/93	15.000	04/30/93
	PARALLELOGRAM, WHITE		EA	1	L	0	.000	0	.000	CP	04/30/93	17.000	05/07/93
										CP	05/07/93	17.000	05/14/93
										CP	05/14/93	8.000	05/21/93
	004.10	M	N			5	2.0000	.000	.000	CP	03/24/93	12.000	03/31/93
	Wing, short yellow		EA	1	L	0	.000	0	.000	CP	03/26/93	4.000	04/02/93
										CP	04/02/93	2.000	04/09/93
										CP	04/23/93	2.000	04/30/93
										CP	04/30/93	4.000	05/07/93
										CP	05/07/93	4.000	05/14/93
										CP	05/14/93	2.000	05/21/93
										CP	05/25/93	16.000	06/01/93
										CP	06/02/93	16.000	06/09/93
	004.20	M	N			5	3.0000	.000	.000	CP	03/26/93	8.000	04/02/93
	Wing, Long Green		EA	1	L	0	.000	0	.000	CP	03/31/93	12.600	04/07/93
										CP	04/02/93	22.000	04/09/93
										CP	04/09/93	26.000	04/16/93
										CP	04/16/93	28.000	04/23/93
										CP	04/23/93	28.000	04/30/93
										CP	04/30/93	30.000	05/07/93
										CP	05/07/93	30.000	05/14/93
										CP	05/14/93	14.000	05/21/93
1	Larry Haverhill												
	000.10	M	Y	FC	C	5	86.0000	.000	.000	CP	03/26/93	1.000	04/02/93
	STARSHIP, MODEL 1		EA	0	L	0	.000	0	.000	CP	04/02/93	2.000	04/09/93
										CP	04/09/93	1.000	04/16/93
										CP	04/30/93	1.000	05/07/93
										CP	05/07/93	2.000	05/14/93
										CP	05/14/93	2.000	05/21/93
										CP	05/21/93	1.000	05/28/93

Appendix D

NYCTA Overhaul; basic organizational description

The research conducted in this study was done at the New York City Transit Authority, Rapid Transit Overhaul division. This is the division of Transit that re-manufactures the subway cars and its major components (such as motors). Unlike the repair and maintenance divisions of Rapid Transit (referred to as the "satellite barns") this shop functions more like a factory, producing finished cars and large components in order to supply both the fleet and maintenance shops. All participants in this study were drawn from a pool of Transit Authority employees who volunteered to participate in the MRP workshops. All of these volunteers expected to have their jobs affected by the planned MRP implementation and for many, the workshops would their only form of introductory training.

A major assumption of this dissertation is that knowledge does not occur in isolation of context and social meaning and that "development" or change in the ways of thinking or knowing must also have some grounding in systems of meaning that are socially constructed. Although these social systems were not the focus of the inquiry reported here, some understanding of them was needed to make sense of the data and also to construct the details of workshop so that the experience would be relevant to the participants. Therefore, in preparation for conducting this study, considerable fieldwork was done on inventory control, shop floor operations and scheduling. Below is a description of the field work done in the months prior to the workshop intervention and a general description of NYCTA Overhaul division's inventory control and the scheduling practices. As explained below, the fieldwork included both observations of shop floor work as well as research into some general operations that have consequences for an MRP implementation.

1. Field observations:

Two types of work observations that are important for a study of this kind. The first broad type concerns observations of the working environment, with the aim of gaining an understanding of the overall goals of the workplace and how these goals are communicated (or not) in shared artifacts and tools. Since people develop an understanding of a domain in a goal directed context with certain tools, and not others, we must understand what information is available, and what are the operating constraints on individuals.

The second kind of observation concerns the perspective or point of view that develops as a function of working in a particular environment or in a particular job. Since this study concerns individual development and aims to track the conceptual changes in individuals' ways of thinking, we must understand in as many ways as possible the "initial" operating mental model that is brought to bear when an individual is working. Evidence of development or conceptual change of any kind simply makes no sense if we have no notion of an individual's starting point.

The two forms of work-place observation require slightly different methods. These are detailed below.

a. Observing the organization of work.

There are three purposes to general observations of the organization of work. The first is to become familiar with the manufacturing environment itself and identify its potential points of contact with the new technology (MRP). This was done by observing with a set of guiding questions: How are various operations that could be potentially affected by MRP handled before implementation, (operations such as the distribution of materials, the accounting and ordering of materials, and the assembly process as it unfolds on the shop floor). What other processes, items and jobs are most likely to come into direct contact with the MRP technology, and in what ways? Whose jobs will change?

The second purpose was to map out the types of activities that lead successful production. Implicit to this analysis is a picture of what the "doers" of these activities must know in order to ensure that the plant's priorities are met. Is the work highly automated and is assembly partitioned, or does successful assembly and quality control depend upon highly skilled craftspersons whose skilled output cannot be duplicated on an assembly line? That is, what aspects of mastery are in the design of the system and which are in the heads of the doers? Concerning the latter, what kinds of knowledge do people in different jobs possess? And lastly, what manufacturing processes are so critical that everyone must have some knowledge of them?

A third purpose for observing the overall organization concerns the discrepancy between work as it is actually done and manufacturing as it is represented. "On paper" items are made according to an engineer's design or analysis of production processes, and "on paper" those who hold different titles do specific tasks associated with that job. However, modifications are often made by skilled workers on the shop floor when materials are lacking or when a design is not working. In addition, daily contact with hundreds of items can inform a shop floor worker's knowledge of the properties of specific objects, and sometimes novel solutions are invented that are invisible to those who are not as deeply engaged with actual production (e.g., engineers). These changes are rarely documented until a great number of them have accumulated. Likewise, aspects of a person's job may bring him or her into contact with "undocumented" responsibilities. Supervisors may have to deal with the personal problems of employees who are not showing up; experienced shop floor personnel may be called upon to identify a viable substitute for a part that has been lost in shipping when a manufacturing order is a priority and cannot be delayed.

In summary, observations of the shop floor can help to tease out the relationship between the actual and the ostensible. Further, such observations can indicate which persons assume the primary responsibility for inventing novel solutions to problems as they arise and whether this role assumption is determined by a worker's knowledge, his/her job description or other factors. Although it is hypothesized that the simulation workshops will exert the primary influence on development, a picture of each individual's role in a larger scheme is helpful in making sense of the "pattern" of development. A study of this kind is a unique opportunity to examine the relationship of prior experience and responsibility to the appropriation of tools and ways of thinking that are radically different but which bear upon the same content.

b. Observations of Individuals:

A major portion of this study concerns tracking actual development from thinking about production processes in one way to developing a new way of thinking about the same processes, with a new set of tools and at a different level of abstraction. In order to track development at a meaningful level, we must understand in detail how people are thinking about and organizing production before learning MRP. A large part of generating a profile of an individual's way of thinking was the use of the probe batteries (see appendix A). However, field observations with actual workers doing work contributed to the further development and refinement of a battery that was previously tested on others, but not tailored to the NYCTA. Such observations also served other purposes. For example, people are rarely aware of what they know, and especially how they know, and are often unaware of how their perception of events in their domain of expertise differs from a non-expert. For this study, workers were observed with the researcher in an "apprentice" role. As previous work has shown (Di Bello and Glick 1992), taking a kind of "apprentice" role yields information more appropriate to a cognitive study of this kind. Passive observation -- or some kind of ethnography -- discloses much about an individual's behavior, but not the thinking behind it; i.e., two people doing exactly the same things could have a very different guiding mental model. Working with an individual does much to expose these implicit categories and differences in the way that experts perceive. In addition, it helps the researcher gain some understanding of the language of work in a specific environment and establish a mode of dialogue with the study participants.

As an "apprentice" the observer is free to ask questions about the "why" of certain actions, the meaning of symbols and other artifacts, the origin of procedures and the "secrets" of the trade. In addition, such a role locates the researcher as a "learner" who wishes to learn more about what an "expert" knows and sees as she or he is actually doing work. In this study, the researcher-as-apprentice role had an additional payoff during post-testing. When the workers saw themselves as being expert "informants", as opposed to "subjects being tested" the interview was regarded by many as a further opportunity to provide information and insights.

NYTCA; overall description

NYCTA Overhaul has two main shops. They are both large 50 acre facilities that reside in the Bronx and Cony Island. These main shops supply parts and whole trains to the satellite barns in all the boroughs. The "south" overhaul shop (in Cony Island) employs 70 mechanics who re-manufacture and repair the trains' pneumatic and valve components. Also, major body work is done in this division (although no body mechanics were involved in this study) The "north" shop handles the "trucks" (the wheels and chassis' of the trains), the electronic parts, the electrical DC controllers and converters (which comprise the motor of a Direct Current electric train) the safety features of the doors and some unique machined parts. Due to both historic practices and the enormous size of the shops, the different sub-divisions function somewhat independently, like a cluster of smaller specialized factories with their own production schedules, supervisors and systems of material flow.

MRP was implemented in Overhaul mainly as an experiment, overseen by the MTA, or the Metropolitan Transit Agency. Like all the transit companies in the New York Area (LIR, Metro North, TA Surface Transit,) TA Rapid is overseen by the MTA (Metropolitan Transit Authority). Eventually, the MTA would like to implement MRP transit-wide (by the year 2,000) and the TA project is considered an informal pilot to this larger effort while it is still being debated and designed. Apparently overstock of unneeded items is an agency-wide problem that the MTA wishes to address with some urgency. Importantly, however, this research was not begun with knowledge of this "grand plan". Rather, it was assumed to be a brainchild of a rather progression Chief Mechanical Officer (the head of the Overhaul division).

The TA's inefficiencies and the resulting overstock problem .

There is considerable tension between unionized workers and salaried managers at the TA. The sources of all this tension are too diverse and unfathomed to detail in this paper, but, importantly, they stem in part from an inefficient work organization and accountability structure.

TA Overhaul was largely a "reactive" organization until very recently. Despite being one of the only public transportation systems in the world with 24 hour, 7 day a week service, it nonetheless had no systematic way of ensuring that enough trains would be in good repair to meet daily demand. Its main system of calculating demand was to wait for breakdowns and attempt to deal with them as rapidly as possible. Often this meant acquiring materials and labor in expensive ways. For example, overtime was a typical way of dealing with increased labor demand, while cannibalizing expensive components that weren't immediately needed for their inexpensive parts (that were direly needed) was a common way of obtaining material. Since the larger, expensive component was then rendered useless, the cost involved was sometimes analogous to buying a new car for its engine.

Cost intensive practices were further encouraged by imposed worker ignorance; until recently the same hourly workers who were required to obtain parts in any manner to meet production schedules were also not permitted to know the costs of parts and sub-assemblies (although, in fact, interviews indicate that employees at all levels are well aware of costs).

Incentives for managers were equally cost inflating. Rather than being rewarded for planning and managing that prevented problems and kept costs down, managers are rated according to their ability to handle crises (even preventable ones), deal with shortages, and produce high output (even if it is unneeded material). In addition, not spending the shop's entire budget can lead to a budget reduction the following year, while overspending can lead to a budget increase. Therefore, managers are also indirectly rewarded for going over budget.

In 1989, the first systematic attempt to predict the demand created by normal car wear and tear was implemented in the form of the Scheduled Maintenance System (SMS). Records of past breakdown, manufacturing/engineer recommendations and even input from the shop floor led to a set of guidelines for systematically replacing parts, components or entire cars that were due for repair or replacement before a breakdown occurred. This was the NYCTA's first attempt at a proactive, rational schedule of future demand and has convinced them that gross overspending can be avoided by proper planning.

However, this system has several flaws too. For example, end items are planned and demand calculated for each part needed to make the items in complete isolation of other parts or the subassemblies that they go into. Therefore, it is often the case that an experienced planner will purchase both a raw material and the sub-assembly that it goes into (which includes all the parts, again). Also, the parts for SMS programs have different part numbers than the same parts not purchased for an SMS program. Therefore, many parts are being purchased for the SMS program even though they are currently in stock somewhere in the vast TA stores.

A final problem resides in the system that does the actual ordering and purchasing of all parts, including SMS programs. The TALON system is a min/max reorder database that automatically triggers a re-order of any stock number, once stock on that item goes below a certain (often arbitrary) "set-point". This has led to many obsolete items from being reordered. It also means that any item purchased for a limited-time SMS project will be re-ordered, even after the project's completion.

Scheduling Methods

Several hours were spent with the director of the TA Overhaul's planning division, in an attempt to understand how planning was done on a yearly, monthly and daily basis. When touring the shop floor, weekly schedules were collected from the foremen and were posted at supervisor stations. We wished to know what logic generated them and if they were effective.

Included in this appendix are samples of these schedules. Even though the planning personnel explained to me that there is an annual grand schedule that forecasts the needs of all of Overhaul's operations, shop personnel do not see the grand plan. As can be seen, there is an annual master schedule which is broken down into monthly and weekly printouts by shop. That is, each shop has the monthly and weekly plan only for its parts, and does not have the "big picture" of the master plan.

These schedules incorporate three sources of demand. The first is the SMS program. Because this is based on actual data about breakdowns and recorded needs, it tends to be realistic and most of the items made to meet this schedule are actually used.

Running Repair is the second source of demand. The quantities calculated for this part of the schedule come from the estimates of material needed for "unplanned" breakdowns, part replacement and all items not included in the SMS plan (parts for which there is insufficient historic data). This portion of the schedule comprises about 80% of all demand and is based almost entirely on history. That is, last year's schedule is simply used again unless there are major objections to any of the line items or quantities. This means that certain practices are replicated automatically, whether they make sense or not (such as over-ordering particular parts) and may also lead to the automatic re-ordering of obsolete parts. The director of planning explained that, unfortunately, there is no formal mechanism for correcting an inaccurate forecast and corrections are not likely unless "somebody really bitches".

If the schedule is unreasonable it is usually changed at the shop floor level to meet more informal but more accurate estimates of demand (see sample schedule with "add-ons" in this appendix) The planners who make the schedule are rarely notified, and the schedule is rarely revised. Part of this practice is due to the accountability structure. Even though planners develop the schedule for all shops, they are not accountable for meeting demand. Since shop floor management <u>are</u> held accountable for getting out needed items, many informal changes are made in the schedule that never get communicated to central planning.

The <u>Hold Car List</u> is the third source of demand and by far the smallest. However, it is the portion of the schedule that gets the most attention. This list contains the parts needed for cars that are being held at the satellite barns as "out of service". In terms of production priorities, the shops' first priority is always furnishing any parts that will put an out of service vehicle back on the tracks. However, the individual shops get the hold car list for only their parts. That is, they have no way of knowing what else, from other shops, a particular car may need. This can lead to a frantic scramble that actually makes no difference in the delivery of service.

An example was provided by an TA employee. If a train derails, a particular car may be all but totally destroyed and take several months to reconstruct. However, the electronic shop gets only notification that the car is being held for certain electronic parts. This can lead to priorities being re-shuffled for the whole week in order to furnish a car with electronic parts even though this car is not going back in service as a result. Given current practice, there is no way of knowing if the "emergencies" on the hold car list are even actual priorities.

Flow of production and Organization of authority and decision making

According to interviews and observations, the weekly and monthly schedules are handled by the shop foremen and division supervisors. The items manufactured and remanufactured for the overhaul division are built by various classes of skilled personnel, such as Air Brake Mechanics (ABMs), Electricians (EMEs), and Electronic Mechanics. ABMs are hourly employees who are trained mechanics with various backgrounds. About half of the participants entered the TA as "car cleaners", after taking a qualifying civil service exam. They received their mechanics training through the TA's "18 month program" a full time 18 month training program that instructs qualified applicants in air brake maintenance and repair. The other half had considerable mechanical work experience before coming to the TA and did not go through the 18 month program. For example, many came from the aviation industry. EMEs, in contrast, have usually received their electrical training outside the NYCTA and have become EMEs after qualifying through civil service examinations. ABMs are mainly responsible for disassembling, cleaning and remanufacturing the components of the Air brake system and the compressor units. EMEs manufacture, re-manufacture or repair the trains' DC and AC electrical components, including the "Controller", the large DC engine that powers the train via the "third rail" on the subway tracks. "Officially", all hourlies are ignorant of the long term schedule or plan for production. They are also not required to think about costs, material availability or consequences of inventory "hoarding" or other work flow issues. However, observations of shop floor practices indicate that they are implicitly accountable for their material practices and have a sense of the long term schedule "in their heads" but are not permitted the tools (such as access to computers or schedules) for anticipating future work demand. One hourly functions as a "material man" for the group, calculating the material needs and stocking often-used parts in the shop's sub-storeroom (usually a 12X12 "cage"). The choices of the stocked material indicate that the shop floor staff have a notion of both seasonal and regular demand. For example, certain parts are more likely to be "hoarded" if a harsh winter is expected. However, "officially" hourlies literally get their orders in the morning and are required to do the day's work as issued by the foreman, by whatever manner they can.

Analysts do the official schedule, both short range and long range. As detailed in the aforementioned chapter, planning managers readily admit that these schedules are often not made in a coordinated fashion, and there is no feedback mechanism for ascertaining if a given forecast or schedule was actually reasonable or not. This may account for the TA's practice of recycling purchasing and production schedules from year to year, whether they have actually met demand or not. In addition to the schedules, the analysts are engaged in the research necessary to acquire the materials needed for production and to meet changing safety regulations. They investigate new products, new designs for common items (such as door switches), new vendors and identify the items needed for and costs associated with various overhaul programs or replacement programs.

Supervisors and managers are required to keep the unionized hourly workforce occupied, schedule the needed skills on appropriate shifts, handle vacations and scheduling issues with personnel, meet the schedule as it comes down from the planning department and handle unplanned demand. They spend much of their time trying to find the material that will help them actually meet the schedule and deal with various material shortages, usually created by unplanned demand (e.g., cars that break down or are involved in accidents). Most supervisors and foremen are former hourly employees with skills similar to the workers they supervise. They have qualified for promotions through civil service exams.

In the production area, managers of various levels are called "superintendent". The top superintendent of all of Overhaul is the Chief Mechanical Officer. Beneath this position are various deputy and assistant superintendents. Like the supervisors and foreman, many of those in these positions have held jobs in the skilled trades and have risen through the ranks. The entire superintendent staff is responsible for implementing and administering the larger goals of overhaul (such as the SMS program), ensuring the quality of the trains and basic budget management. These individuals also manage personnel engaged in various special projects to improve the trains themselves (investigating new equipment, parts or train designs) and oversee the planning staff.

All workers interviewed were aware that the MRP system would be reorganizing the priorities of the shop to be more cost efficient and more pre-planning oriented. Most were unclear about how their jobs would actually be affected.

Flow of production

All the material produced in the overhaul shops is shipped to the "satellite barns" all over the New York City area, where the components are put on the trains. The only complete trains that the Overhaul Division works on are those that are being completely overhauled after several years of service.

Complete overhaul involves completely gutting the train cars and fitting the remaining shells with all new components and interior fixtures, such as seats, floors and windows.

The majority of mechanics are involved in producing the assemblies that are replaced on trains that are in service, but in need of partial overhaul (e.g., a train may require a new DC motor). As indicated above, each mechanic gets his daily assignments at the beginning of each shift from his foreman or supervisor.

After each mechanic gets his or her assignment for the shift, he or she can obtain materials either on his own or through the "material man". Many of the mechanics use the Talon or CMS computer system to get part numbers, check balances and write up their orders before going to the satellite storeroom to get the parts they need to begin work. As work is completed it is tested by other mechanics who specialize in testing components and finished assemblies. Once the item is ready for shipment to the satellite barns, it is given a unique serial number (for tracking and accountability), logged by stock number, serial number, description and mechanic, and then packed into a wooden shipping box. The wooden shipping boxes are sturdy, re-usable containers with compartments inside for packing a number of similar parts. Once the item is shipped to the satellite barn, it is marked off on the schedule. Schedules are not kept or turned back in to planning or upper management in order to evaluate the schedule's feasibility. If there is insufficient material to meet the schedule, it is either not satisfied, or met by cannibalizing other assemblies, trains or portions of trains. (After more than 40 years, there are a lot of pieces of train lying around the shops). Again, these problems are not reported to the planning department and shops generally meet demand by their own devices, using the schedule as a "guide" to what they should produce. If there is not enough work on the schedule, or if the shop is forced to wait for parts before completing the schedule, a supervisor or foreman may elect to give other work to mechanics, preparing for future schedules or simply to use the material that is available.

How MRP has affected production

MRP has had a problematic implementation at TA Overhaul. The major predicted problem was resistance on the part of the hourly workers. Our workshops were seen as a way to help mitigate against luddite behavior. This effort is considered by NYCTA management to have been largely successful -- worker attitudes are the least of the problems encountered and after a year and a half while the workshops themselves have continued at the request of NYCTA management. In the meantime, the MRP staff continues to try to solve a number of technical problems. Briefly, it is difficult to implement a modern, inter-borough LAN in two 50 acre shops that are over 45 years old and have neither the modern electrical wiring nor the kind of physical conditions required for maintaining computers. In addition, the NYCTA MIS department has been slow to build an interface between the NYCTA Materiale Department's material database and MRP. Since it impossible to independently maintain the balances of literally hundreds of thousands of parts within TA Overhaul, this interface with central NYCTA databases is greatly needed.

Partly due to pressure from the now MRP savvy hourlies, managers and supervisors, the system has been implemented on a limited basis on the shop floor, and is used to schedule the large compressor units that Overhaul has begun to control, independently from the TA's central purchasing operations. The same is planned for a number of upcoming programs that will be handled separately within Overhaul. In a sense then, one of the largest remanufacturing facilities is using MRP as a small business would.

The biggest blow to the implementation efforts came when the CMO (Chief Mechanical Officer) who began the effort was moved to another division of the TA. There was some initial talk about "pulling" the system. The new CMO is deeply ambivalent about the system's usefulness, but is under pressure from the MTA and the workers to continue with the process.

Why do this study at the TA?

There were four main reasons for choosing this site over other factory possibilities for research. The first concerned the relative MRP naivete of the participants; unlike many manufacturing and re-manufacturing workers in private industry, these workers were, by and large, completely ignorant of MRP and its pervasive spread through industry. In addition, the TA is about 10 years behind in other decision support technology used in manufacturing. More than any other site observed in ongoing research, this facility had greater numbers of workers using traditional manufacturing methods and technology.

A second attractive feature of the TA is related to the first. It was in the process of implementing MRP for the first time. This gave a rare opportunity to observe a brand new implementation with "uncontaminated" learners.

Thirdly, TA Overhaul was under considerable pressure from its then-General Superintendent to operate more like a private, for-profit industry. Historically, the TA had a history of extreme overbuying, leading to stores of obsolete, overstock material valued at $95 Million. When the NYCTA requested state assistance in meeting its operating budget, the governor's office tried to reduce costs by farming out some of the overhaul work to upstate private remanufacturers. This considerably depleted the work available to local NYCTA re-manufacturing workers and threatened the next generation of employees (Unionized TA workers are tenured and nearly impossible to lay off). Many current employees have indicated that the shops currently operate with one third the number of workers of years' past, and feel an indirect threat to job security, expressing the fear that their unions could protect their jobs only so far if, in fact, there was no work for them. It seemed that the clear message of cost-reduction that pervaded the sites when the study began would induce workers to take MRP and its potential seriously.

Fourth, the same CMO who permitted our access had once been a unionized, hourly worker himself in his early years and was sympathetic to the notion of shop floor workers being actively involved in using and understanding MRP. He had arranged to install the PC LAN terminals <u>on the shop floor</u> as well as in the offices of managers and analysts. This was an extremely rare and potentially important difference between TA Overhaul and other sites, which consider computers to be office tools and computer users as needing formal education (e.g., college or management training) before even qualifying for learning about the general goals of MRP, or even for participation in a study such as this one.

In retrospect, the willingness of upper management to allow workers to freely access MRP and its databases may have stemmed from ignorance about the system more than an enlightened attitude, but the net effect is the same; this study allowed examination of the relationship between formal education, work history and the development of MRP concepts.

We were also hoping that, as the study progressed, the technical and political difficulties would become resolved. All the data discussed in this study are from subjects who work at the Cony Island shop, where MRP is actually being used. At this writing the Bronx shop is just beginning to be put "on line" and -- because of the changes in upper management -- "real" use of MRP is just beginning again in the Cony Island shop and for the first time in the Bronx.

Sample Shop Schedule

from Planning department

with "add ons" by foremen and mechanics

LAB Copy

ELECTRONIC LAB WEEKLY R/R SCHEDULE RC 2582 R. NESSEN

Week Ending Mar 18, [illegible]4												03/14	03/15	03/16	03/17	03/18		
COMMODITY #	DESCRIPTION	TOTAL R/Q	S/R 80 OPS		S/R 30 & 80 SMS						1994 FORECAST	MON	TUE	WED	THU	FRI	TOTAL PRODUCED	1994 USE YTD
08-29-3802	PC BD. PROP. LOGIC	1	1								48	1	1	1	1 1		1	
08-[illegible]-0002	PO[illegible]PLY, F/LOGIC R62A	1	1								81	1	1	1	1 1	1	1	
08-62-0003	PROPULSION. LOGIC ([illegible] BOARD) R62A	0									148	1	1	1	1	1		
08-62-1061	HARNESS, F/PROP. LOGIC PA	2	2								18	1	1	1	1	1		
08-62-2250	FIELD FO[illegible] PANEL	4	4								38.98	1	1	1 2	1	1	2	
08-62-2251	RELAY	2	2								0.[illegible]	1	1	1	1	1		
08-[illegible]	PC BOARD	1	1								12	1	1	1	1	1		
08-62-2650	CARD	4	4								[illegible]5.92	1	1	1 4	1	1	4	
08-68-1017	PROP.BOARD	2	2								72	1	1 2	1	1	1	2	
09-33-3612	PANEL	1	1								12	1	1	1	1	1		
09-33-3804	PANEL. U/W MAIN CONTROL	4	4								249.6	1	1	1	1	1		
09-33-3805	PANEL	4	4								124.8	1	1	1	1	1		
09-33-3901	MODULE	0									60.84	1	1	1	1	1		
09-36-[illegible]251	PANEL	1	1								12	1	1	1	1	1		
09-38-2470	CARD. AE	1	1								84	1	1 1	1	1	1	1	
09-46-1004	PANEL	1	1									1	1	1	1	1		
09-46-1031	R[illegible]Y. OVERLOAD	2	2								0	1	1	1 2	1	1	2	
09-46-2256	PAN[illegible]L ASSY	2	2								[illegible]	1	1	1	1	1		
09-46-[illegible]3	749	2	2									1	1	1	1	1		
09-46-4518	CARD	2	2								12	1	1	1	1	1		
09-46-4655	MODULE	1	1									1	1	1	1	1		
09-62-1751	OVERLOAD RELAY	2	2								175	1	1	1 2	1	1	2	
09-62-2350	CARD	14			14						158.9	1	1	1	1	1		
09-62-2351	CARD. AW "C"	16	2		14						350	1 1	1	1	1 10	1	11	

ELECTRONIC LAB WEEKLY R/R SCHEDULE ... 2582 R. NESSEN

Week Ending	Mar 18, 1994											03/14	03/15	03/16	03/17	03/18		
COMMODITY #	DESCRIPTION	TOTAL REQ	S/R 80 OPS		S/R 30 & 80 SMS						1994 FORECAST	MON	TUE	WED	THU	FRI	TOTAL PRODUCED	1994 USE YTD
09-62-2352	CARD AE	14			14							I	I	I	I 10	I	10	
09-62-2353	CARD AD	16	2		14						202	I	I	I	I	I		
09-62-2355	CARD AC/AX	16	2		14						418.9	I	I	I	I	I		
09-62-2359	CARD, 1419	1	[illegible]								63.96	I	I	I	I	I		
09-62-2363	CARD, 1418	2	2								12	I	I	I	I	I		
09-62-2364	CARD, FL	16	2		14						720	I	I	I	I	I		
12-40-1060	CARD, E McGRAW-EDISON	1	1								19.08	I	I	I	I	I		
12-40-1062	EDISON CARD D(12-40-1124)	0									26.16	I	I	I	I	I		
12-40-1201	PC BOARD ASSY, GLC CONVERTER	2	2								32.88	I	I	I	I	I		
12-40-1203	G.T.O., THYRISTOR ASSY	2	2								21	I	I	I	I	I		
12-40-1205	ASSY. CONTACTOR PANEL U/O	2	2								15.36	I	I	I	I	I		
12-42-2071	PC BOARD	3	3								114	I	I	I 1	I	I	1	
12-42-2317	CARD	2	2								30	I	I	I	I	I		
12-42-23[illegible]	CARD, A3	2	2								18	I	I	I	I	I		
12-42-2338	CARD, P.C. FIRING	0									18	I	I	I	I	I		
13-32-1627	SIGN END RTE (ELECTRONIC)	1	1								42.96	I	I	I	I	I		
13-44-9200	CONTROL UNIT, LCD SIGN R-44	0										I	I	I	I	I		
13-44-9201	OPER. KEYBOARD DISPLAY LCD	1	1									I	I	I	I	I		
13-44-9205	SIDE SIGN, LCD R-44	2	2									I	I	I	I	I		
13-46-9001	LCD SIGN UNIT R46	2	2								3	I	I	I 1	I	I	1	
13-46-9003	LCD SIGN SYS R46	2	2								3	I	I	I	I	I		
13-46-9036	POWER SUPPLY	3	3								9	I	I 1	I	I	I	1	
13-46-9038	PC BOARD	2	2								[illegible]	I	I	I	I	I		
17-36-0020	RELAY	2	2								24	I	I	I	I	I		

SHOP LOADING (212) 544-3319 MAST_LAB.XLS

ELECTRONIC LAB WEEKLY R/R SCHEDULE RC 2582 R. NESSEN

Week Ending: Mar 18, 1994 COMMODITY #	DESCRIPTION	TOTAL REQ	S/R 80 OIS		S/R 30 & 80 SMS						1994 FORECAST	03/14 MON	03/15 TUE	03/16 WED	03/17 THU	03/18 FRI	TOTAL PRODUCED	1994 USE YTD
17-36-0090	..C BOARD	0									163	-	-	-	-	-		
17-36-0240	B...RD ASSY	[illegible]									264	-	-	-	-	-		
17-36-0241	CIRCUIT BOARD P.C.	1	1								213	-	-	-	1	-	1	
17-36-0243	BOARD ASSY	0									193	-	-	-	-	-		
17-36-0290	PC BOARD	1	1								131	-	-	-	1	-	1	
17-40-..41	CARD	1	1								84	-	-	2	-	-	2	
19-62-9401	CHIME ASSY		4								51.96	-	-	-	-	-		
26-60-0355	TIMER	0									157	4	-	-	-	-	4	
60-60-6450	AMPLIFIER, INTERCOM ASSY	10	10								180	-	1	2	2	-	5	
50-60-6499	RADIO BKT ASSY	3	3								250	-	-	-	-	-		
60-60-6506	MIC PLATE	12	12								645	-	2	-	6	-	8	
60-60-....	AMPLIFIER	[illegible]	12								1602	3	-	3	3	-	9	
60-60-6544	MIC PLATE R62.R62A	0									339	2	-	-	4	-	6	
60-60-7001	AMP. INTERCOM MIDWEST	0										-	-	-	-	-		
60-60-7002	AMP. MIDWEST	0									27	-	-	-	-	-		
60-60-7003	AMP. MIDWEST	2	2								98.98	-	-	-	-	-		
60-60-7004	MIC PLATE, MIDWEST		2								0	-	-	-	-	-		
83-32-7046	MOTHERBOARD, A/C R-32	0										-	-	-	-	-		
83-32-7057	MOTHERBOARD, A/C R-32	1	1									3	-	-	-	-	3	
83-36-9406	SENSOR, ...ATIC, TEMP., FOR A/C R-33	0									287	-	-	-	-	-		
83-42-1303	COMPARATOR BOARD	2	2								30	-	-	-	-	-		
83-44-9162	CARD, PTR/TDR SAFETY	2	2									-	-	-	-	-		
83-46-0166	RELAY	2	2								48	-	-	-	-	-		
83-62-0547	PC BOARD Matrix Board	2	2								30	-	-	-	-	-		

SHOP LOAD: (212) 544-3319 MAST_LAB.XLS Page 3 OF 4 3/11/94

ELEC~~ONIC LAB WEEKLY R/R SCHEDULE RC 2582 R. NESSEN

Week Ending Mar 18, 1994											03/14	03/15	03/16	03/17	03/18		
COMMODITY #	DESCRIPTION	TOTAL ?Q	S/R 80 OPS		S/R 30 & 80 SMS						1994 FORECAST	MON	TUE	WED	THU	FRI	TOTAL PRODUCT	1994 USE YTD
83-62-0590	PC BOARD	0									82.08	I	I	I	I	I		
83-62-0912	COMPARTOR BOARD	2	2								180	I	I	I	I	I		
83-62-0913	T.D.R. P.C.BOARD	2	2								157.9	I	I	I	I	I		
83-68-0554	MOTHERBOARD	0									42	I	I	I	I	I		
83-68-0578	PC BOARD, A/C PTR	1	1								42	I	I	I	I	I		
83-68-0?15	PC BOARD	0									42	I /	I	I	I		/	

COMMODITY NO	Component Description	DESTINATION	MON 3/14	TUE 3/18	WED 3/1?	THU 3/19	FRI 3/1?	TOTAL 3/1?
09-38-2375	ACS ComCARD	TO S/R 30 FOR CORONA	1		5	3		9
09-38-2425	AX ScanCard	TO S/R 30 FOR Corona	3		1	1		5
09-62-2355	AC/AX	TO 207th ST. Barn CAR#3998 AC#2569	1					1
09-62-2355	AC/AX	TO 239th ST. BARN CARS 7914 & 15 AC#2568	2					2
83-62-0912	Compensator Card	TO Pelham AC#2562	P					1
8382-0913	TDR	TO Pelham AC#2562	2					2
83-32-7196	Compensator board	TO S/R 30 ShelF	1					1
60-60-6942	Long mux plate	TO S/R 30 ShelF	2					2
60-60-8508	Chrome Amp	TO Coney Island M/S Car #4165		1				1
09-62-2355	AC/AX	TO Jamaica CAR 0820 & 0935		2				2
17-36-0240	Zero Set Comp	TO Pelham CAR 9548		2				2
17-36-0241	MG243-4	TO Pelham CAR 9548		2				2
17-36-0242	MG241-4	TO Pelham CAR 9548		2				2
83-36-9406	Temp Sensor	TO Pelham CAR 8595		1				1
09-38-2320	AA Scan	TO S/R 30		1				1
09-38-2425	AX Scan	TO S/R 30		2				2
13-46-9002	ODK	TO S/R 30		1				1
08-68-0223	OPTICAL SENSOR	TO Pelham CAR# 8592		1				1
09-62-2253	PWR MODULE	TO S/R 30 ShelF		1				1
09-33-3804	DBRT UNITS	TO 180th ST. Car (9120)(9121)(9250)(9251)			4			4
09-62-2355	AC/AX Scan Cards	TO Corona Car Hold #9727			1			1
09-62-2355	AC/AX Scan Cards	TO Jamaica Car Hold# 1105 & 1113			2			2
83-46-1019	Temp CONTROL BOARD				1			1
09-62-2355	AC/AX Scan Card	TO 239th ST. Car Hold# 8728				1		1
08-68-0223	OPTICAL Sensor	TO 240th ST. Car Hold# 2238				2		2
83-62-0547	Mother Board	TO Pelham Car Hold# 1685				1		1
83-62-0912	Compensator BOARD	TO Pelham Car Hold# 1685				1		1
83-62-0913	TDR PS BOARD	TO Pelham CAR Hold# 1685				1		1
~~09-3?-2560~~	AV Scan CARD	TO S/R 30 For Corona				1		1

Full Set of "Hold Car" Lists

(Each shop gets only those sheets with their items, as noted on each sheet)

NEW YORK CITY TRANSIT AUTHORITY
MANHATTAN and BRONX SURFACE TRANSIT OPERATING AUTHORITY

DATE: 03/25/94

TO: J. McKENDRY, D/SUPT., MACHINE SHOP

FROM: J. RABADI ATMA

SUBJECT: HOLD CARS

SUPPORT SHOP SIGNSEAT

BARN	CAR #	COMMODITY #	DESCRIPTION	QTY	CAR EQUIV	POT REL	NO WORKING STOCK	DATE HELD	DATE SHIPPED
CI MS	4254	13-40-5493	SIDE DESTINATION SIGN	2	2	0	Y	02/25/94	________
				TOTALS	2	0			

APPROVED ____________________

SIGNATURE ________________________

(RRHOLD.RP1)

NEW YORK CITY TRANSIT AUTHORITY
MANHATTAN and BRONX SURFACE TRANSIT OPERATING AUTHORITY

DATE: 03/25/94

TO: J. CURCIO, D/SUPT., PNEUMATIC SHOP

FROM: J. RABADI ATMA

SUBJECT: HOLD CARS

SUPPORT SHOP PNEU

BARN	CAR #	COMMODITY #	DESCRIPTION	QTY	CAR EQUIV	POT REL	NO WORKING STOCK	DATE HELD	DATE SHIPPED
239th	8697	18-62-9046	VALVE, Feed, F6	1	2	2		03/24/94	
240th	2240	18-62-8596	COMPRESSOR UNIT, D4	1	1	1		03/24/94	
240th	2226	18-62-9713	HOUSING ASSY, Top	1	1	1		03/24/94	
240th	2404	18-62-9713	HOUSING ASSY, Top	1	1	0		03/24/94	
240th	2404	18-62-9713	HOUSING ASSY, Top	1	1	0		03/24/94	
CONC	2548	18-62-9069	LOAD SENSOR, SR Reducing	2	1	0		03/20/94	03/23/94
CORONA	9682	18-77-6410	BRAKE VALVE, ME-42B	1	2	2		03/24/94	
E180	8876	18-15-8225	TRIPCOCK, D-1-A, IRT	1	2	2		03/24/94	
E180	8877	18-29-2368	RELAY VALVE, J14 CSB12	1	2	2		03/17/94	03/24/94
E180	8979	18-29-2368	RELAY VALVE, J14 CSB12	1	2	2		03/18/94	03/24/94
JAM	0512	18-38-0097	HEAD ASSY, Hi Press Cyl, D3 & D4	1	4	0		03/23/94	
JAM	0508	18-38-1600	TRIPCOCK, D-1, IND-BMT	1	4	0		03/23/94	
JAM	1138	18-44-9648	GOVERNOR, Electro-Pneumatic	1	4	0		03/24/94	
JEROME	1455	18-62-9002	BRAKE VALVE, ME-43	1	5	0		03/18/94	03/24/94
			TOTALS		32	12			

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SIGNATURE ____________________

(RRHOLD.RP1)

NEW YORK CITY TRANSIT AUTHORITY — MANHATTAN and BRONX SURFACE TRANSIT OPERATING AUTHORITY

DATE: 03/25/94

TO: P. SILIATO, SUPT., MOTOR SHOP

FROM: J. RABADI ATMA

SUBJECT: HOLD CARS

SUPPORT SHOP MOTOR

BARN	CAR #	COMMODITY # DESCRIPTION	QTY	CAR EQUIV	POT REL	NO WORKING STOCK	DATE HELD	DATE SHIPPED
CI MS	4255	09-62-0252 MOTOR, Pilot	1	2	0		03/24/94	______
CI MS	4241	83-46-0104 MOTOR, A/C Blower/Evap, 5CY1047E	1	2	2		03/20/94	______
CI MS	4311	83-46-0104 MOTOR, A/C Blower/Evap, 5CY1047E	1	2	2		03/22/94	______
		TOTALS		6	4			

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SIGNATURE ______________________

(RRHOLD.RP1)

NEW YORK CITY TRANSIT AUTHORITY

MANHATTAN and BRONX SURFACE TRANSIT OPERATING AUTHORITY

DATE: 03/25/94

TO: R. NESSEN, D/SUPT., ELECTRONIC LAB

FROM: J. RABADI ATMA

SUBJECT: HOLD CARS

SUPPORT SHOP LAB

BARN	CAR #	COMMODITY #	DESCRIPTION	QTY	CAR EQUIV	POT REL	NO WORKING STOCK	DATE HELD	DATE SHIPPED
CONC	2548	08-68-0223	PC BOARD, Optical Sensor	1	1	0		03/20/94	03/22/94
CORONA	9584	09-33-3805	LOAD WEIGH TRANSDUCER PANEL, 17M	1	2	0		03/22/94	03/23/94
CORONA	9584	17-36-0293	RELAY, A/C, T-16101-8	1	2	0		03/21/94	
CORONA	9584	83-36-9406	SENSOR, Static Temp	1	2	0		03/21/94	03/23/94
ENY	4744	09-33-3804	PANEL, Main Control, DBRT, 17MM1	1	2	0		03/24/94	
ENY	4745	09-33-3804	PANEL, Main Control, DBRT, 17MM1	1	2	2		03/24/94	
ENY	4695	09-62-2355	CARD, Static, AC & AX	2	2	0		03/23/94	03/24/94
ENY	4695	09-62-2364	CARD, Static, KM Slowdown, 17FC5	2	2	2		03/23/94	03/24/94
JAM	0508	09-46-4625	PANEL, Converter	1	1	0		03/21/94	
JAM	1138	13-46-9100		1	4	0		03/14/94	
JEROME	1577	09-62-2364	CARD, Static, KM Slowdown, 17FC5	1	5	0		03/23/94	03/24/94
PELHAM	1675	83-36-9406	SENSOR, Static Temp	1	1	1		03/22/94	03/23/94
PELHAM	9520	83-36-9406	SENSOR, Static Temp	1	2	2		03/22/94	03/23/94
PELHAM	9521	83-36-9406	SENSOR, Static Temp	1	2	2		03/22/94	03/23/94
			TOTALS		30	9			

15-62-9713 ②

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(RRHOLD.RP1)

NEW YORK CITY TRANSIT AUTHORITY

MANHATTAN and BRONX SURFACE TRANSIT OPERATING AUTHORITY

DATE: 03/25/94

TO: T. KOCZON, SUPT., ELECTRIC COMPONENT SHOP

FROM: J. RABADI ATMA

SUBJECT: HOLD CARS

SUPPORT SHOP E/B

BARN	CAR #	COMMODITY #	DESCRIPTION	QTY	CAR EQUIV	POT REL	NO WORKING STOCK	DATE HELD	DATE SHIPPED
239th	7845	19-26-8003	DOOR OPERATOR, Center	1	2	0	Y	03/17/94	________
CI MS	2641	08-62-0229	CYLINDER & INTERLOCK ASSY	1	1	0		03/24/94	________
CI MS	2737	19-62-8006	GEAR HOUSING ASSY, LH, Door Oper	1	1	1		03/24/94	________
CI MS	2882	19-62-8006	GEAR HOUSING ASSY, LH, Door Oper	1	1	0		03/24/94	________
CONC	5090	08-62-0435	ARC BOX	1	1	0		03/19/94	03/21/94
JAM	0508	13-44-1394	KEEPER, Upper, End Door	1	4	0		03/21/94	03/22/94
JAM	0730	13-44-1394	KEEPER, Upper, End Door	1	4	0		03/21/94	03/22/94
JAM	0512	17-40-6029	RELAY, Control	~~6~~	2	0	Y	12/05/93	________
JAM	3736	19-32-1502	DOOR OPERATOR, Opp Cab	1	2	2		03/23/94	________
JAM	0508	19-46-2634	DOOR OPERATOR, RH	1	4	0	Y	03/13/94	________
PELHAM	1859	08-42-1850	RELAY, UA-218-E	1	1	0		03/23/94	________
PELHAM	1819	19-62-8005	GEAR HOUSING ASSY, RH, Door Oper	4	1	0		03/23/94	03/24/94
PELHAM	1819	19-62-8006	GEAR HOUSING ASSY, LH, Door Oper	4	1	0		03/23/94	03/24/94
			TOTALS		25	3			

805 #10

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(RRHOLD.RP1) Page 1

NEW YORK CITY TRANSIT AUTHORITY — **MANHATTAN and BRONX SURFACE TRANSIT OPERATING AUTHORITY**

DATE: 03/25/94

TO: P. SILIATO, SUPT., BATTERY SHOP

FROM: J. RABADI ATMA

SUBJECT: HOLD CARS

SUPPORT SHOP **BATTERY**

BARN	CAR #	COMMODITY #	DESCRIPTION	QTY	CAR EQUIV	POT REL	NO WORKING STOCK	DATE HELD	DATE SHIPPED
CI MS	4254	13-05-2708	BATTERY, 100 Amp	1	2	0		02/25/94	________
LIVONI	2055	13-68-0775	BATTERY, 80 AmpHr, 25 Cell, 5x5,	1	1	1		03/24/94	________
PELHAM	1819	13-68-0775	BATTERY, 80 AmpHr, 25 Cell, 5x5,	1	1	1		03/13/94	________
			TOTALS		4	2			

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(RRHOLD.RP1)

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