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Organizational Rules in Computer Systems: Explaining the Use of Manufacturing Resource Planning Systems

A dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Philosophy

in Information and Computer Science

by

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Dedication

For SMC.

This work is 50% hers by law,

and 100% hers by inspiration.

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Abstract of the Dissertation

Organizational Rules in Computer Systems:
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Resource Planning Systems

by

Jonathan P. Allen

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This research provides a new understanding of computerized information systems that embed organizational rules—rules that describe how organizations, and the people within them, should behave. All computer systems create a model of some problem domain. Today, the same concepts are used to understand the design and use of computer systems that model organizational behavior, abstract mathematical problems, and physical objects. Research on human organizations strongly suggests, however, that formal models of organizational behavior, used by people in the course of their work, have their own unique challenges. The question then is, what new concepts do we need to think about the design and use of these systems? What different choices do we have? What different processes must we pay attention to?

To address this larger issue, I study the use of Manufacturing Resource Planning (MRP2) systems, an ambitious attempt to create a simulation of the manufacturing firm through an elaborate set of computerized organizational rules. To explain the problems manufacturing firms have using the full MRP2 model, I present a new theory of computer systems as an organizational modeling process. I argue that the challenges of organizational modeling are a better explanation of why full MRP2 use is difficult to achieve than existing theories of individual behavior ("lack of discipline") and narrowly-conceived technical problems ("data inaccuracy"). Through a series of in-depth studies, I show how MRP2 users see partial conflict as a fundamental part of the MRP2 modeling process, how the failure to use parts of the MRP2 model is associated with differences in organizational activities supported simultaneously, and how people creatively use shared interpretations to reconcile the different uses of MRP2.

Chapter 1

The Challenge of Designing, and Using, Organizational Rules in Computer Systems

This research provides a new understanding of computerized information systems that embed organizational rules—rules that describe how organizations, and the people within them, should behave. All computer systems create a model of some problem domain. Today, the same concepts are used to understand the design and use of computer systems that model organizational behavior, abstract mathematical problems, and physical objects. Research on human organizations strongly suggests, however, that formal models of organizational behavior, used by people in the course of their work, have their own unique challenges. The question then is, what new concepts do we need to think about the design and use of these systems? What different choices do we have? What different processes must we pay attention to?

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In this introductory chapter, I discuss how the computing disciplines (computer science and information systems) see computer systems as embedding a model of some problem domain. Is modeling the behavior of human organizations—embedding computerized organizational rules—different from other kinds of modeling? I argue that the long history of research on formal organizational rules shows that organizational models bring new challenges. I then address the question of how to study this class of computer system, which I call ORBIS (Organizational Rule-Based Information Systems). At the end of this chapter, I summarize this dissertation research, and outline its contributions to research in the computing disciplines.

1.1 Computer Systems as Models

To a great extent, the computing disciplines[1] understand the construction of computer systems as a model building activity, and the use of computer systems as a model using activity. In the field of computer science, leading theoreticians (e.g., Wirth, 1986) put modeling at the heart of their discipline. According to Aho and Ullman (1992; 1):

> computer science is a science of *abstraction*—creating the right model for a

[1]The computing disciplines is my term for the major academic areas of research concerned with computer-based information systems. The computing disciplines include *computer science*, which has traditionally been concerned with the efficient automation of computation, and *information systems*, which has traditionally been interested in the useful application of computer-based information systems to real world activity. Though historically different, there is significant overlap in their mainstream theoretical approaches (e.g., general systems theory), and in specific research areas (e.g., software engineering, computer-supported cooperative work).

problem and devising the appropriate mechanizable techniques to solve it.

This view of computer science is particularly relevant for the construction of computer software. According to the *Encyclopedia of Software Engineering* (Marciniak, 1994; 698):

> software engineering is all about the definition and design of processes and process support facilities for the creation of adequate model of phenomena and processes in the real world.

Researchers in the field of information systems also see modeling—usually understood as the optimizing models of operations research—as central to their discipline (e.g., Davis and Olson, 1985; 6-10). Systems analysis and design, activities central to the information systems field, are characterized as modeling activities, and the end products—information systems—are defined as "models of reality" (Wand and Weber, 1989; 79).

Despite the importance of modeling, and the widespread recognition that modeling issues (such as problem framing, requirements engineering, and systems analysis) are among computing's most difficult problems (e.g., Walker, 1994), computer science has been criticized for not having an explicit theory of modeling and the modeling process (Smith, 1995). What appear, in my eyes, to be extremely difficult problems—deciding what relevant aspects of the outside world to model, and how to usefully characterize the relationships between things computationally—are quickly passed over in fundamental computer science texts such as Aho and Ullman (1992).

If we think of all the real world phenomena that computer systems are frequently called upon to model, modeling the behavior of human beings (as opposed to mathematical or physical objects) would seem to be one of the most difficult. Yet computer systems used by organizations are routinely called upon to model the behavior of people, through the embedding of organizational rules. What are organizational rules? Organizational rules are simplified descriptions of how people *should* behave in particular organizational situations. They are "expectations for interaction" (Walsh and Dewar, 1987; 218-219) that are remembered and understood over time by a relatively large number of people. "All workers must be at the office by 8:00 AM" and "if the purchase amount exceeds $5,000, the purchasing manager must approve the purchase" are examples of organizational rules. In the example of MRP2 used in this research, computer systems contain a multitude of embedded scheduling rules, purchasing rules, engineering change rules, production scheduling rules, inventory use rules, and financial activity rules. These organizational models assume that, in some sense, human beings are acting in accordance with the rules.

We have good philosophical reasons for believing that modeling human behavior is a different, and more difficult, kind of challenge than other kinds of modeling. Consider the relationship between the computational model that computer professionals must create, and the problem they are trying to solve. For a mathematical problem, the relationship is straightforward—both the problem and the computational model are symbolic creations. Predicting the behavior of many physical systems through computational models is effective, as the successes of the natural sciences show, though philosophers do not completely understand why (Davis and Hersh, 1981; 68-76). Human beings acting in organizations, however, are different. Human beings are reactive; they change; they are intelligent, adaptive, kind, and cunning (Wolfe, 1993; Lincoln and Guba, 1985). Wind patterns do not change when you program a weather simulation; cold fronts do not scheme against you and use the model in their own interest (though, programming late into the night, they might seem to!). Human beings do react to models, such as organizational rules, whose purpose is to maintain a specific kind of behavior in organizations.

We have more than philosophical arguments, however, to help us understand why and how organizational rules might be a particularly difficult modeling problem. Decades of research in organizational sociology can tell us much about the relationship between organizational rules and human behavior.

1.2 How Are Organizational Rules Different?

Seeing computing as a modeling activity raises a practical question: can computer systems that include organizational rules be designed and evaluated in the same way as computer systems that model mathematical and physical phenomena— systems that control elevators, find prime numbers, and simulate global weather patterns? Anyone with experience working in an office or factory might suspect that the relationship between the rule "be at work at 8AM" and what actually happens in organizations is complicated—complicated because it depends on human behavior, rather than the formal definitions of mathematics, or the predictable, deterministic behavior of the physical world.

Research in organizational sociology has spent decades studying what they refer to as *rationalization*, or the increased calculability and predictability of human behavior in organizational settings, often through the use of formal organizational rules (Weber, 1946). European social scientists at the end of the 19th century, such as Max Weber, were trying to understand how the (then) recent growth of rationalized bureaucracies in government and private business started, how it spread, and how it would ultimately affect society (Weber, 1946; Sica, 1988). Ever since, organizational researchers have asked questions about rationalization, which they have seen as the distinguishing feature of organizations. When do people obey formal rules? How are formal rules used? What types and degrees of rationalization are suited to particular organizational and industry characteristics? What exactly *is* the relationship between formal organizational rules and human behavior? One of the fundamental debates in organizational sociology, even today, is whether organizations should be thought of as primarily formal rule-following and formal goal pursuing (the "rational" view of organizations) or not (the "natural" view of organizations) (Scott, 1992).

Previous research on organizations tells us that the relationship between organizational rules and human behavior has many aspects. Consider, for example, the simple rule "if the purchase amount exceeds $5,000, the purchasing manager must approve the purchase". Previous studies of organizations give us many clues about how this simple rule might be used in complicated ways:

- **The rule allows efficient, routine behavior.** The rule can be used as a template for quick, efficient, and calculable action by giving all parties a clear, unquestioned procedure to follow (Weber, 1946). Using the rule helps people cope with the uncertainty of a relatively stable situation in an economically efficient way (Galbraith, 1977). The rule creates two categories of purchases, provides an automatic means of assigning purchases to a category, and impersonally specifies the approvals necessary. Because the rule is a simplifying model, however, it cannot capture the situation completely (Burns and Flam, 1987).

- **The rule provides a basis for power and influence.** As rule use makes selected actions more efficient, it also formalizes a claim on power and influence in the organization (Walsh and Dewar, 1987). This rule officially gives the purchasing manager grounds for controlling the behavior of others, and formally justifies the manager's existence. Over time, many people in organizations with limited resources work hard to preserve and extend their ability to act, i.e. their power. Expanding the bureaucratic rule base is a common strategy for doing this (Michels, 1949). The rule also serves as a standard by which people can be rewarded or punished—as a standard of justice for both managers and subordinates (Walsh and Dewar, 1987).

- **The rule gives one focused, limited view of the situation.** For instance, this rule concentrates a person's attention on one aspect of the purchase (price) and one course of action. Especially in changing circumstances, other relevant information may be ignored. Some purchase orders over $5,000 may be more routine, or the person creating them may know more about the situation than the manager. The rule helps focus people's limited cognitive attention (March and Simon, 1958), but can also blind people to alternatives if the rule has been in place for so long that people can no longer imagine alternatives (Zucker, 1977).

- **The rule can be selectively applied.** For many uses, invoking the rule only in certain situations makes the rule more effective. For managers trying to reward and punish subordinates, selectively enforcing rules is a common strategy for increasing their discretion (Fortado, 1994; Gouldner, 1954). The selective use of rules can also be an important source of power and influence for those at the bottom of the hierarchy (Crozier, 1964). For instance, they could threaten to overload the purchasing manager with work that he or she does not normally deal with, and knows little about. Selective rule use can also benefit the organization if it is used to reward or punish the behavior of outside clients (Blau, 1955). If a supplier doesn't cooperate, a person could threaten to make all their orders difficult by sending them up the hierarchy.

- **The rule is a symbol,** used to evaluate the organization and the people within it.

Some rules are adopted by organizations because they are a sign of competence and professionalism (Meyer and Rowan, 1977). Having an established purchasing procedure is the mark of a serious organization, no matter what their daily work needs are. Within the organization, how people do or do not use rules can be a symbol of their reputation and status. Is this person defying the purchasing manager? Is this person overly controlling? Cooperative? Rule use in this sense is a kind of group membership test, giving people information about where a person's allegiances lie, and whether they can be trusted to perform certain activities.

- **The rule is a bargaining position.** How people use rules is usually tied to long-standing agreements that have been negotiated over time (Strauss, 1986). Managers, for example, often trade or bargain with the enforcement of rules to receive other favors in return (Dalton, 1959). Not conforming, or over-conformance, can lead to a breakdown that requires time-consuming renegotiation, or even retaliation. Playing in an organizational game with commonly understood rules, however, builds solidarity and limits competition to officially approved forms (Burawoy, 1979).

- **The rule may or may not be seen as legitimate.** How the rule is used may depend on how it was created. Rules that people see as being in their own interest, and created fairly, tend to be used much more faithfully than a rule which is perceived as arbitrary and not in their interest (Gouldner, 1954).

- **The rule may overlap with other formal or informal rules.** More than one rule can always be applied to a situation (Burns and Flam, 1987). In this case, the purchasing rule might conflict with other organizational rules which call for rapid customer service. Other, more informal rules of social behavior might label the purchasing manager as "unreasonable", for example, if they insist on "following the book" in every case.

This brief overview of the organizational research on rationalization makes two important points for technologists about the problems of rule use. First, human action and human choices are intimately involved in all of these rule uses. Rationalization, in Weber's terms, requires that people accept the legitimacy of formal organizational rules, and orient their own action towards greater calculability and predictability (Weber, 1946). There is no automatic, deterministic link between organizational rules and human behavior. Second, the relationship between formal rules and behavior depends on a number of forces acting simultaneously. A rule can be used to serve administrative efficiency needs, political goals, and reaffirm or challenge cultural values simultaneously (e.g., Walsh and Dewar, 1987). The rationalization seen in an organization at any particular time is born from the combination (both historical and current) of forces that organizational researchers have found to be important, such as the technical and legitimacy demands faced by an organization (e.g., Powell and DiMaggio, 1991).

1.3 The Problem of ORBIS

In my research on the use of MRP2 systems, which I report on in this dissertation, the problem of embedded organizational rules in computer systems quickly became a major focus. By the end of my series of MRP2 use studies, it became clear that problems with using the full MRP2 model were better explained by the difficulties of computerized organizational modeling than by technical inadequacy or recalcitrant users. This result opens up the more general problem of what I now call ORBIS, or Organizational Rule-

Based Information Systems.[2]

ORBIS is a class of computerized information systems that depends on the use of embedded organizational rules. MRP2 is an excellent example of an ORBIS, because it embeds an elaborate set of detailed organizational rules, and its functioning is completely dependent on these rules. Workflow is another type of computer system that belongs well within the ORBIS class. To the extent that any computer systems embeds organizational rules, and is dependent on their use, the computer system is subject to the problem of ORBIS. The general problem with ORBIS-class computer systems is that the real world phenomena an ORBIS attempts to model—behavior in organizations—is not only complex in a wholly different way from other common modeling activities, but the relationship between the model and the phenomena itself is complicated by the understandings and motivations of human beings.

To separate ORBIS from other kinds of computer systems is to make a claim that computationally modeling human behavior in organizations is different from other kinds of modeling. Perhaps it seems too obvious to claim that modeling organizations is somehow different from modeling boxes, elevators, money, quality defects, and network traffic. As far as I know, however, no research in computer science or information systems has yet made this claim. It is not surprising that computer science, which owes its tremendous success to the fact that so much *can* be done by reducing the world to computation, does not make any distinction. It is perhaps more surprising in the field of information systems, which is concerned with the application of computer systems. Mainstream theory in information systems (e.g., Davis and Olson, 1985) sees both computer systems and organizations as information processing systems; according to this view, organizations can

[2]The concept of ORBIS was first proposed by Rob Kling.

be computationally modeled as well as any other phenomena. However, many different "alternative" approaches to information systems research have been put forward recently to cope with the complexity of information systems and organizations—both alternative theoretical approaches (using, for example, structuration theory, resource dependency theory, symbolic interaction, and hermeneutics; e.g., Orlikowski and Robey, 1991; Walsham, 1993) that do not conceptualize technology and organizations as strictly information-processing systems, and alternative approaches to system building and evaluation (e.g., Greenbaum and Kyng, 1991) that include previously marginalized groups. Though this alternative information systems literature opens up new conceptual and practical roles for people in computing, it does not distinguish the technical content of a system that models organizational rules from other kinds of models (Walsham, 1993).

The problem of ORBIS is also a research problem—how should we study the use of an ORBIS? As I began this research, I sought a research approach that would help me better explain the difficulties of using MRP2. I was convinced by the argument that an interpretive research approach—one that considered human meanings and motivations as central—was needed for a system so dependent on organizational rules. Conceptually, and empirically, rationalization depends on people's interpretive understandings (Weber, 1946; a full explanation of the interpretive research approach is in Chapter 3.1). However, I also wanted an approach that would take advantage of previous research on rationalization in organizational sociology. And, I wanted to study the actual content of the computer system—the organizational rules within—rather than simply focusing on the organizational context, or the process of organizational change (Walsham, 1993). None of the current alternative approaches to information systems (as reviewed in Chapter 7.4) could satisfy all these demands; to meet all three criteria, I turned to a framework for combining interpretive and positivist research (Lee, 1991), as described in Chapter 3.

1.4 Summary of the Dissertation

In this dissertation, I present a new explanation for why manufacturing firms are able to regularly use a limited subset of MRP2 functionality, but have problems using the full MRP2 model. This new explanation was created, and given a preliminary test, through a series of in-depth studies guided by Lee's (1991) research framework. MRP2 systems provide an elaborate set of computerized organizational rules for the entire manufacturing firm. Their pattern of use is puzzling. MRP2 systems are widely adopted, but they are considered notoriously difficult to implement, and have been condemned for eroding manufacturing competitiveness in the United States. Previous explanations of why using the full MRP2 model is so difficult, based on individual behavior problems ("discipline") and narrow technical problems ("data inaccuracy"), did a poor job of explaining this MRP2 use pattern, and left manufacturers with few useful options for improving their information use.

Lee (1991) argues that existing explanations may be flawed because they are based on an inadequate *interpretive* understanding of how people in organizations see the world, and attribute meanings to their actions. Rather than blaming bad employees, or criticizing their tolerance of data inaccuracies, I use a series of case studies to generate a new explanation of why the full MRP2 model is so difficult to use. A study of MRP2 professional training suggested that problems using parts of the MRP2 model arose because of the very different activities that were linked together through a single set of computerized organizational rules. This theory was tested at an award-winning electronics manufacturer, where large differences between linked activities in technical uncertainty, institutional demands, and beliefs about legitimate behavior were associated with all of the failures to use the full MRP2 model (as defined by Wight, 1984). A participant-observer study at this same company revealed the importance of people's orientations towards work/benefit imbalances, trust in the information, and the legitimacy of evaluation for explaining when parts of the MRP2 model are or are not used.

This new explanation of problems using the full MRP2 model—the problem of embedding organizational rules in computer systems—is applicable, I argue, to other Organizational Rule-Based Information Systems (ORBIS). I present a new theory of ORBIS use derived from my study of MRP2. In this theory, an information system is seen as a set of simplifying organizational models that are used as a basis for human action. These models make simplifying assumptions about organizational rules and categories, in order to support specific human activities. The assumptions made in the models do not support all activities equally well, which explains the ease or difficulty organizations have in linking together different activities through integrated computer systems with embedded organizational rules. It is an organizational modeling *process* because it is ultimately through use by people that information takes on its meaning and affects organizational action (Orlikowski and Robey, 1991).

1.5 The Research Contribution

My examination of why using the full MRP2 model is so difficult makes contributions to the computing disciplines, and to manufacturing research. Most obviously, my explanation of MRP2 use as organizational modeling makes a contribution to the research on MRP2 adoption (e.g., Cooper and Zmud, 1990; Sum and Yang, 1993), MRP2 implementation (e.g., Roberts and Barrar, 1992), and MRP2 use. Manufacturing production control is an important computing domain in its own right. My study results are consistent with the claim that the difficulties of organizational modeling are a more powerful explanation of why parts of the full MRP2 model are difficult to use than the explanations found in these literatures (as discussed in Chapter 2.5).

Contributions to the general literature on computer science and information systems are discussed in Chapter 8. This study offers a reconceptualization of the problem of organizational modeling. It also provides a theoretical argument that links organizational sociology concepts (describing different organizational demands faced by activities) to a set of technical choices (how to link organizational activities together through shared organizational rules). I consider this an important project because it opens the possibility that organizational concepts can be used to inform a class of technical decisions. This is especially important for large-scale computer system architectures, with their biases towards tight integration and centralization (e.g., Goodhue et al, 1988). If the severest problems with these architectures are enforcing discipline and improving data accuracy, then the ideology of integration that prevails in the information systems field (e.g., Iivari, 1991) makes complete sense. But if the problems are due to overextension—trying to support too many organizational activities—then technologists need some way of accounting for the organizational difficulties caused by embedded organizational rules. It no longer makes sense to use a body of technical design knowledge that does not consider the relationship between organizational rules and organizational behavior to be a problem.

On a methodological level, this study uses frameworks such as the comparative case study method (Ragin, 1994) and Lee's approach to combining positivist and interpretivist research (Lee, 1991) for the first time in the computer science/information systems fields.

This study also provides, to my knowledge, the first participant-observer study of information systems work within organizations—certainty, the first participant-observer study of information systems work in manufacturing. Lee's approach in particular provides a powerful way of exposing and challenging the interpretive understandings that underlie many of the theories used in information systems research—shallow understandings such as "resistance to change" that still haunt the field.

On a practical level, my studies of MRP2 contribute a much-needed, concrete example of organizational modeling issues in computing. Scholars arguing over the subtle complexities of organizational rule use through computers (for instance, in computer-supported cooperative work research) have few studies to point to. The manufacturing world has a dramatic story of conflict between a vision of elaborate, computerized organizational rules, and a vision of much simpler, often non-computerized rules. The computing disciplines have much to learn from the debate in manufacturing information systems. For example, the detractors of complex MRP2 systems have called for *simplicity and focus* in information use. Simplicity and focus is an easy shorthand for a kind of information strategy that tries to minimize the organizational complexity we see around MRP2 use. Simplicity is one way of calling for a reduction in the amount of time people spend determining the trustworthiness of their information, and whether they are being evaluated fairly. Focus is one way of calling for systems that do not try to support partially conflicting organizational activities at the same time, and for systems that do not incorporate flagrant work/benefit imbalances. This is just one example of a practical insight that could come from an awareness of the MRP2 story in the computing disciplines.

Chapter 2

MRP2 Use in the United States

MRP2 (Manufacturing Resource Planning) systems have had an interesting history in the United States over the past 25 years. In this dissertation, I try to provide a new explanation of the difficulties of using the full MRP2 model that will be useful for understanding the successes and failures of any large, integrated computer system that embeds many organizational rules. Failures to use the full MRP2 have been blamed on individual behavior problems (such as a "lack of discipline") and narrow technical problems (such as "data inaccuracy"). Unfortunately, these explanations do a poor job of explaining the pattern of MRP2 use we see most often: widespread adoption of a limited subset of MRP2 functionality.

This chapter provides a brief introduction to MRP2, its controversial recent history, and what we know about MRP2 use. First, MRP2 is described as a system that tries to improve manufacturing scheduling by modeling more and more of the organization. Next, I discuss why MRP2 systems have been partially blamed for the reduced competitiveness of US manufacturing in the 1970's and 1980's, and present the alternative visions of simple, often non-computerized information support for indirect administrative activities that arose in its place. The studies of MRP2 use are reviewed to show that adoption of a limited subset of MRP2 is common—the organizational models can only be stretched so far. Finally, I discuss why currently accepted explanations of MRP2 fall short of accounting for commonly seen patterns of MRP2 use.

2.1 What is MRP2?

MRP2 (Manufacturing Resource Planning) is a term coined by Wight (1984) to describe the computer systems used by manufacturing companies to schedule the buying and making of parts. Though MRP2 systems cover many aspects of "capacity planning, inventory control, product costing, shop floor control, finance, marketing, engineering, and human resource management" (Harrison, 1990; 56), their main job is to help the company decide what it needs to order, what it needs to make, and when.

In this section, I will first present the conventional definitions of the three commonly accepted levels of MRP2: MRP, closed-loop MRP, and MRP2. These conventional definitions focus on the software modules typically included in an MRP2 system. After presenting these definitions, however, I will discuss MRP2 as a "simulation of reality" (Wight, 1984; 53) that provides "one set of numbers" for the entire company (Wight, 1984; 54). Though not many other experts have taken Wight's emphasis on MRP2 as an organizational simulator seriously, I argue it is very useful to see MRP2 as a system that tries to improve scheduling by modeling more and more of the organization.

Wight defines three levels of MRP2: MRP, closed-loop MRP, and MRP2 (Table 1). MRP (Material Requirements Planning) systems maintain a valid schedule of when to order materials, based on how much material is needed and how long it takes to purchase. MRP maintains an accurate schedule by modeling the parts structures of end products, the available inventory in stock, and the time it takes to make or order parts. For example, with an MRP system, we can model the fact that a table requires four legs. Every time an order for 100 tables is entered, the system will automatically generate a request for 400 legs. The MRP system can also model the time it takes to make or buy parts. If we tell the system it takes one week to order legs from a supplier, then the MRP system will automatically request an order for 400 legs one week before the order for 100 tables is needed. MRP also models the available inventory. If 250 legs are already in stock, the MRP system will only request 150 legs.

Table 2.1: Defining Three Levels of MRP2

Level of MRP2	Wight (1984) Definition	Typical Software Modules
MRP	Priority planning - determining when to order materials based on the schedule for items that use the material. (p. 49)	Inventory Control Bill of Materials Purchasing Material Requirements Planning Master Production Schedule
Closed-loop MRP	MRP + capacity planning, shop floor scheduling, vendor scheduling, and feedback from the vendors, factory, and planners when there is a problem executing the plan. (p. 50)	Routings and Work Centers Order Entry Capacity Requirements Planning Shop Floor Control
MRP2	Closed-loop MRP + financial systems (business plan, product costing) and a "what if" simulation capability. (p. 51)	Cost Accounting Accounts Payable Accounts Receivable Financial Analysis

Closed-loop MRP includes the functionality of MRP, but adds capacity planning and shop floor scheduling. One problem with the original MRP was that it did not consider the factory's capacity to produce parts. MRP would generate a schedule for producing 100 tables without any knowledge of whether the factory was capable of producing 50 tables or 500 tables that week. By modeling the capacity of the factory to produce each part, and the typical sequence of operations that parts would go through as they were being assembled, closed-loop MRP ensures that the schedule it creates is never impossible to achieve, given its model of the factory. By accepting detailed feedback from the shop floor, closed-loop MRP is also able to readjust the schedule because of unforeseen problems such as equipment breakdowns.

MRP2 includes all the functionality of closed-loop MRP, but adds more support for the financial system and factory simulation. Wight, unfortunately, does not give one clear definition of MRP2 in his book. The major difference he emphasizes is that "tying the financial and the operating system together was the big step from closed loop MRP to MRP II[1]" (Wight, 1984; 52). Accounting and manufacturing operations should "use the same transactions" and "use the same numbers" through MRP2 (Wight, 1984; 53). MRP2, according to Wight, also has a "what if" capability to "simulate what would happen if various policy decisions were implemented." (Wight, 1984; 53). A version of Wight's simplified MRP2 diagram appears in Figure 1.

The popular and research literature on MRP2 continues to use Wight's three level definition. What has been largely forgotten is Wight's emphasis on MRP2 as a "simulation of reality" (Wight, 1984; 53), a term he uses repeatedly in his book. For Wight, the top level of MRP2 is a

> whole company system now, involving every facet of the business because the things that MRP II is concerned with - sales, production, inventories, schedules, cash flow, etc. - are the very fundamentals of planning and controlling a manufacturing or distribution business. (Wight, 1984; 54)

Through each level of MRP2, the computer system is able to maintain a more valid and accurate schedule by creating a model of more of the manufacturing organization: first by modeling part structures, purchasing lead times, and inventory; then factory capacities and shop floor processes; and finally the financial accounting systems and overall business plan. The highest level, MRP2,

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[1]MRP II is Wight's original abbreviation. I use the term MRP2, which I find less confusing. MRP II is the same as MRP2.

> results in management finally having *the numbers to run the business*. One set of numbers, valid numbers, and everybody using the same set of numbers. (Wight, 1984; 54)

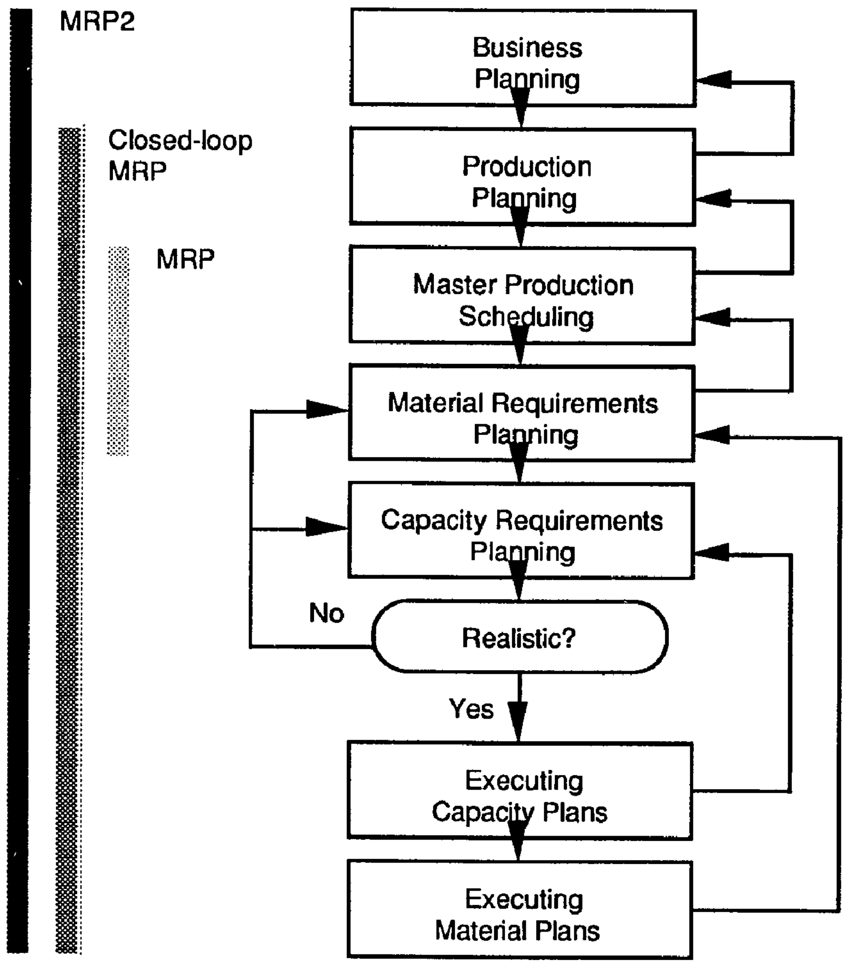

Figure 2.1: MRP, Closed-loop MRP, and MRP2 (adapted from Wight, 1984; 54)

The original vision of MRP2 was to present a simulation of enough of the manufacturing firm to maintain a valid, up to date schedule. This comprehensive simulation would be able to tell a production planner the impacts of any proposed schedule change. To do this, the typical MRP2 system has to model a vast number of organizational rules and procedures: inventory rules, purchasing rules, scheduling change rules, accounting rules, engineering change control rules, sales policy rules, credit rules, etc. Even at the simplest MRP level, creating a model of the amount of available inventory requires modeling many organizational rules. What is the inventory removal policy? LIFO or FIFO? Do we keep track of different lots and locations? At what level of detail? How often are inventory records updated? How many different categories of inventory are there, and how is each determined? Are there only 'available' and 'not available' parts, or are there also parts that are 'available with some work', 'available but use others first', 'available but if they fail its the suppliers fault and they should be charged for it'?

The MRP simulation also has to provide process models that define the timing and sequencing of organizational activities. Basic MRP provides a simple process model: it takes so long to either make or buy a part, and each part may require other parts to be made or bought first (e.g., a table can't be assembled until the legs are screwed or nailed together). Adding capacity planning to MRP requires adding a much more elaborate process model of production activities, with variable timings and conditional routings. The rules and process models in an MRP2 organizational simulator make these systems useful for studying how organizational rules are built into computer systems.

2.2 Blaming MRP2 for US Manufacturing Failure

When the first "MRP crusade" was launched by IBM and APICS (American Production and Inventory Control Society) in the early 1970's, heavy computerization of production planning was considered a sensible strategy for US manufacturers. US manufacturers still dominated most global markets, and the most serious threat appeared to be low-wage foreign labor. Computerization and automation were seen as the most logical tools for beating low cost foreign competitors.

Throughout the 1970's and early 1980's, MRP and MRP2 systems received favorable reviews from the press and the experts. There was some talk of implementation problems, but many of the non-technical discussions of MRP and MRP2 were short, upbeat articles in trade magazines that claimed very high payoffs (the review in Ettlie, 1988; 40-41, for example, contains many of these accounts). As late as 1984, Wight claimed that MRP2 was responsible for reducing the severity of the 1980-81 US recession.

By the late 1980's, however, it was clear to many analysts that key US manufacturing industries—automobiles, steel, machine tools, consumer electronics—had slipped badly compared to foreign competition, especially Japan. At first, Japan's success was explained by their low-wage labor, their unique culture, and their higher automation of factories. As the first detailed accounts of Japanese manufacturing management began to reach the United States in the early 1980's, however (e.g., Schonberger, 1982; Schonberger, 1986), people noticed that US manufacturing firms were using computer technology very differently than their Japanese counterparts.

Japanese manufacturers used computer technology more extensively and effectively for direct production activities than their US competitors: robotics, flexible manufacturing systems, and computer numeric controlled machinery (e.g., Jaikumar, 1986). US manufacturers concentrated on using large computers for indirect administrative and planning activities such as scheduling, purchasing, quality control, and accounting—in other words, for MRP2. US manufacturers, when they saw detailed descriptions of Japanese factories, could hardly believe that Japanese companies used such simple tools for managing their famous just-in-time environments: charts and pencils, whiteboards, paper

Kanban cards, and painted squares on the floor.

As studies of manufacturing effectiveness looked more closely at management practices and the use of technology, an influential group of US experts made it very clear which kind of information system they preferred:

> We have spent over a decade and millions of dollars developing elegant Materials Requirement Planning systems, while the Japanese were spending their time simplifying their factories to the point where materials control can be managed manually with a handful of Kanban cards. (Dertouzos et al, 1989; 95-96).

This quote was taken from *Dynamic Manufacturing* (Hayes et al., 1988). In *Dynamic Manufacturing*, the authors compare a company using traditional American manufacturing practices ("Factory A") with a company using the new Japanese-inspired management techniques ("Factory B"). Factory A assumed that "computers offered the best means for coping with the factory's increased complexity" (Hayes et al, 1988; 192) and took great pride in their "centralized", "sophisticated", and "specialized" MRP2 system (Hayes et al, 1988, 193). Factory B, in contrast, had "simplified layouts and production flows" that made it "unnecessary to use large-scale information systems to manage production on the shop floor" (Hayes et al, 196). Factory B used parts of an MRP system for longer-term planning, but the decentralized departments had considerable freedom to manage their own information flows. Less information was processed at Factory B "because its systems are simpler, more visual, and controlled locally" (Hayes et al, 1988; 249).

> rather than trying to prespecify responses for every possible response, those directly involved [at Factory B] have great flexibility to respond to situations as they arise (Hayes et al, 1988; 249).

The book left no doubt that Factory B was the best choice for manufacturers.

By the 1990's, the conventional wisdom on MRP2 shifted. MRP2 systems were still widely used, but they were frequently condemned in the same terms used by Hayes et al, as a "disappointment" that "requires simplification" (Ronen and Pass, 1992), a "fragile" system with an "80% failure" rate (Underwood, 1994; 14), and as a "failure of cooperation" that kept functional areas in manufacturing firms from working together productively (Dertouzos et al, 1989; 94). Manufacturing textbooks changed their descriptions of MRP2:

> Large MRP II systems, however, are complex and expensive, and usually include a relatively large number of software modules in relation to those which are often required. They can take long periods of time to implement, and often do not realise their full potential through lack of understanding. Few companies apparently have implemented MRP II systems successfully. (Nicholson, 1991).

Even enthusiasts of the technology increasingly admitted that MRP2 systems have particularly severe implementation problems (King and Ramamurthy, 1992; Duchessi et al, 1989; Roberts and Barrar, 1992; Umble and Srikanth, 1990). MRP2, because it advocated an approach so different from the successful Japanese manufacturers, came under attack as overly complex, expensive, and, ultimately, a competitive disadvantage to US industry. Some Europeans wondered if Americans had been blinded by a "cultural bias" towards the use of complex computer systems such as MRP2 (Wobbe, 1990) that were celebrated as an "American solution" that "does not require a study trip to Japan." (Duchessi et al, 1989).

2.3 An Alternative Vision of Information Support

The detailed accounts of Japanese manufacturing practices found in Schonberger's *World*

Class Manufacturing (1986), Greif's *The Visual Factory* (1990), and Suzaki's *The New Shop Floor Management* (1991) provide a stark contrast to the MRP2 vision. Their pictures of the ideal factory (Suzaki, 1991; 14; Greif, 1990; 17) do not include centralized computer systems for indirect, administrative activities such as planning and scheduling. Schonberger (1986; 45) calls for "better information with less data processing" and "simple models, simple systems". As part of his celebration of Japanese manufacturing practice, Schonberger claimed that, for enlightened US companies,

> a growing number of production managers...have rid their shop floors of computer terminals. (Schonberger, 1986; 45).

The advocates of this Japanese-inspired vision stress that factories should be "simplified". Simplification implies that all factory activities, including management and administration, should be understandable at the point where the product is made (i.e., on the shop floor). According to this vision, one of the key benefits of the focused, simplified factory is the simpler (and cheaper) information support needed to keep it running. This simplified information support should be more visual, and more closely connected to where the work actually happens.

Why the emphasis on simplicity? According to Underwood (1994; 15), the Japanese approach to manufacturing emphasizes "frugal methods" that try to reverse the "spiral of expense, complexity, and fragmentation" that curse many factories (Underwood, 1994; 16). One key to removing the waste trapped in the "hidden factory" (Vollmann et al, 1993; 281) is to eliminate as much indirect administrative work as possible, and allow the workers and engineers to make quality and scheduling decisions. The hidden factory is reduced by simplifying production, and by reducing the time it takes to perform activities.

While the simplified factory has many supposed benefits, advocates claim that the simplification of the factory's information systems is crucially important. Like the critics of MRP2, supporters of this alternative vision see manufacturing computing systems as overly complex (Steudel and Desruelle, 1992; 307-310; Harmon and Peterson, 1990; 204). Instead of supporting an expensive data processing bureaucracy, simplified systems "orient control towards decision making for action" (Steudel and Desruelle, 1992; 310) and "encourage workers to be alive to seeking ways to improve" (King, 1985; 103-105). In a world where manufacturing success depends on continuous improvement from the workers, information must be visual—something that everyone can see at the point of work (Suzaki, 1993; 6-8). To encourage action, everyone

> must be convinced that they could have written the fact, or the goal, on the board. (Greif, 1990; 12).

Despite the increasing abilities and decreasing costs of modern computers, these analysts argue for drastic reductions in the amount of factory computing. Harmon (1992; 95), for example, calls for a 90% reduction in the number of transactions processed. Why? Because of the need for decentralization.

> For decades...many computer technicians have extolled the advantages of the massive, centralized data base to which everyone in the organization has access and with which staff employees can police operations from their ivory towers. In the new world in which small, focused factories-within-a-factory are treated as entrepreneurial business units...these focused factory managers need small, local computer system support. (Harmon, 1992; 15).

And because of technical complexity.

> the concepts of focus and simplicity (small and simple is best) must become fundamental characteristics of twenty-first century computer operations...most systems today are so highly integrated that even small improvements require further convoluting the logic and structure of innumerable computer programs...New systems, however, must be simpler

> and less intertwined to support substantially lowering the cost penalty associated with changing a business organization's subsystem. (Harmon, 1992; 95).

Even the latest textbooks for APICS certification argue that Japanese manufacturing techniques require changes in the way computers are designed and used. "Large centralized computer system will tend to be used less than local systems" (Vollmann et al, 1993; 281), and should be discarded when no longer needed. The implications for computer professionals are "profound":

> they need to continually "prospect" for new computer packages that the users might be able to apply, determine the minimal set of information that has to be maintained on a centralized basis, and encourage the users to concentrate on problems rather than esoteric solutions (Vollmann et al, 1993; 281).

After decades of experience with MRP2, a large computer system that creates an elaborate model of the manufacturing organization, manufacturing experts have developed an alternative vision of information support that stresses what they call simplicity, focus, and visibility. I discuss this vision not because it is 'right' and others, such as MRP2, are 'wrong'. I discuss this vision because it reflects commonly held perceptions of a long and sometimes painful learning process, in which manufacturers tried to find the appropriate roles for computer systems that build in many organizational rules. Greif describes the learning process at NUMMI, a famous US car factory managed with Japanese techniques, in this way:

> [He] did not disdain computers. He merely meant that his plant had adopted a particular mode of organization in which the cry to computerize everything had been abandoned. Computers were being used only in carefully selected situations.
>
> To understand NUMMI's outlook—which many other firms have adopted—we must recognize that during the 1970s and 1980s, computer technology appeared to be a miracle cure for managing the complex

> problems of production units...Visual production control differs fundamentally from this perspective. Simultaneously, visual production control contributes to simplification of decision-making systems and to broader employee participation in managing production units. (Greif, 1990; 99-100).

Unfortunately, the computing disciplines have displayed a distressing lack of curiosity about why so many manufacturing experts feel the need to make this point.

2.4 How Has MRP2 Been Used?

Careful studies and decades of experience give us extensive knowledge of how MRP2 systems have been used. After reading the serious critiques of MRP2, you might think that few US manufacturers would buy and use MRP2 systems. You would be wrong. MRP2 sales are substantial. MRP2 systems for production planning and control are among the most adopted of all advanced manufacturing technologies (Ayres and Raju, 1992; King and Ramamurthy, 1992), at least for companies above a certain size.

MRP2 systems may be widely adopted, but to what extent are they used? Do companies only use the limited functionality of MRP, or are they able to use the more elaborate and complete models of the organization found in closed-loop MRP and MRP2? The most carefully done surveys of MRP2 tell us that, most often, only a limited subset of MRP2 is used.

Table 2 shows the use pattern from the two most carefully done studies of MRP2 use in the United States. According to the ABCD rating scheme introduced by Wight (1984), very few US manufacturing companies rate themselves at the Class A level, which is equivalent to a working MRP2 level system (Harrison, 1990; 58). Roughly a third rate themselves at the Class B, or closed-loop MRP, level. Around half only report themselves as Class C users, at the lowest MRP level. Class D users report little use of MRP2 outside of the computer department. This pattern of MRP2 use is consistent over almost a decade of technology improvements.

Unfortunately, the Class ABCD rating scheme introduced by Wight (1984) closely, but does not exactly, correspond, with the three levels of MRP2 he defines. The definitions in square brackets for Class A, B, and C exactly match his definition of MRP2, closed-loop MRP, and MRP, but Wight also includes evaluations of how well the company is performing certain activities (shown in parentheses in Table 2). This is a possible source of confusion (Cooper and Zmud, 1990; 129). Nevertheless, these results are consistent with the observations of MRP2 from the expert literature. US companies are rarely, if ever, able to put Wight's full MRP2 dream into practice. Most often, only a limited subset of MRP2 is successfully used. Only so much of the elaborate MRP2 organizational model is routinely put into practice.

This "limited success" pattern of MRP2 use was also found in a recent survey of MRP2 use in Singapore (Sum and Yang, 1993). Sum and Yang concluded from their survey that most MRP2 users were not at the Class A or Class B level. The manufacturers in Singapore were held back by only moderate use of MRP2 accounting modules, but even more by the infrequent use of shop floor control, capacity planning, and detailed shop floor scheduling. Singaporean manufacturers also find the limited model of MRP—inventory control, purchasing, and to a lesser extent master scheduling—much more workable in practice that the company-wide simulations of closed-loop MRP or MRP2.

Table 2.2: US MRP2 Use Patterns

	Anderson et al, 1982	Cooper and Zmud, 1990
Class A [closed loop; priority planning and capacity planning; master schedule used by top management] (most deliveries on time; little or no expediting)	9%	3%
Class B [closed loop; priority planning and capacity planning] (master schedule somewhat inflated; top management not fully supportive; capacity sometimes exceeded; some expediting)	29%	34%
Class C [priority planning] (master schedule inflated; expediting; modest inventory reduction)	49%	47%
Class D [data processing only] (many records inaccurate; little benefit)	13%	16%

2.5 Problems with Existing Explanations of MRP2 Failure

How do the experts explain why MRP2 is widely adopted in the US, yet only a limited subset is commonly used? All of the commonly accepted explanations of MRP2 failure, even to this day, are captured in Wight's (1984; 125) three critical elements for MRP2 success:

- Technical
- Basic data
- People

These critical elements "are what it takes to make MRP work" (Wight, 1984; 126). Problems with any of these critical elements lead to failures. Technically, the system software and hardware should function correctly. Basic data, such as inventory numbers and production schedules, should no longer be "inaccurate". The people using the system must be "disciplined" enough to obey the system when it is not in their immediate interest, educated enough to understand the system, and "committed" to the success of the system (including upper management, line supervisors, and shop floor workers).

These explanations of MRP2 failure are popular in both the trade press and the research literature. The review of MRP2 studies in Cooper and Zmud (1990) reveals only these simple explanations. The typical studies of critical success factors in MRP2 implementation (e.g., Roberts and Barrar, 1992) consider many variations of these three critical elements. The literature is still using Wight's three critical factors as the way to think about MRP2 failure.

Unfortunately, as sensible as Wight's three critical MRP2 factors may seem, they do a poor job of explaining the most commonly found pattern of MRP2 use. These critical factors are not only inadequate for explaining the MRP2 failures we see—particularly the difficulty of moving from closed-loop MRP to MRP2—but leave manufacturers with few useful options when they face MRP2 difficulties. Consider each of these explanations.

The *technical* explanation argues that MRP2 use fails because of the malfunction of computer software and hardware. Technical malfunctions would, of course, cause any level of MRP2 use to fail. This explanation would only predict large differences in the failures of MRP, closed-loop MRP, and MRP2 if there were substantial technical differences between them—differences in technical complexity, or reliability. But there are not large technical differences between these three levels. Moving from closed-loop MRP to MRP2 does require a few more software modules, and perhaps a few more terminals, but "the technical differences" between closed-loop MRP and MRP2 "are small" according to Wight (1984; 54). Most of the technical complexity comes in installing the initial computer system, network, operating system, and database. The incremental increase in technical complexity is very small in the move from closed-loop MRP to MRP2, and cannot explain the large gap in successful use.

The *basic data* explanation argues that MRP2 use fails because data that "didn't have to be right" before MRP2 now has to be more accurate (Wight, 1984; 125). Regardless of whether inventory and scheduling data is always "more accurate" than in other non-computerized production control systems (the authors cited in section 2.3 would argue it is not), this explanation does not account for why capacity planning data, shop floor scheduling data, and financial data are consistently more difficult to keep accurate than inventory, product structure, or master schedule data. Accurate data should be a challenge for all aspects of MRP2, especially rapidly changing inventory information. Yet high inventory accuracy through MRP2 is common (as we see in the relatively high use of basic MRP functionality), while accounting data must, according to this argument, be especially inaccurate, because of the high drop-off rate from closed-loop MRP to MRP2.

The *people* explanation argues that MRP2 use fails because of undisciplined, uneducated, or resistant people using the system. This explanation could only account for the MRP2 use pattern we see by arguing that the individuals who participate in an MRP level system (located in inventory, engineering, and planning) are consistently more disciplined and educated than the individual users who join the system in a move to closed-loop MRP (capacity planners and shop floor schedulers), who in turn are consistently more disciplined and educated than the accountants and top management who join the system in a move to MRP2. The people explanation looks at problem individuals, however, and would expect these problem individuals to be more equally spread among all the users of MRP2.

None of these three explanations of why parts of the full MRP2 model fail to be used—technical, data, or people—leave manufacturers with useful options when they encounter a problem with MRP2. Either they should exchange their current system for a technically superior one, improve the accuracy of their data across the board, or improve the discipline and education of their employees. These options do not help manufacturers decide what appears to be the key question: how far should we go? Should we try to work with the relatively simple organizational model of MRP, or should we try to use closed-loop MRP or MRP2? Which functions should we include, and which should we exclude? These are important questions, since very few manufacturers are able to use the full functionality of MRP2 successfully.

One other explanation of why the full MRP2 model is not used, tested in recent studies, might provide an answer. This explanation argues that a good fit between the task to be accomplished and the technology leads to successful use of the full MRP2 model (Cooper and Zmud, 1990; Sum and Yang, 1993). The *task-technology fit* argument suggests that the level of MRP2 use depends on the complexity of the manufacturing task faced by a company. Unfortunately, this promising explanation has led to contradictory results. Cooper and Zmud (1990) concluded that simpler manufacturing tasks were associated with more extensive use of the MRP2 model, while Sum and Yang (1993) found that more complex manufacturing tasks had more extensive use of the MRP2 model.

I believe that the contradictory findings on task-technology fit come from the emphasis on task rather than tasks. Full MRP2 systems support a bewildering array of activities in organizations, some very different from the others. Understanding that the levels of MRP2 use try to support and interconnect progressively more activities is the key, I will argue, to explaining when parts of the full MRP2 model are or are not used. Through the in-depth studies of MRP2 use that follow, I try to create a new explanation of why companies fail to use parts of the full MRP2 model. The problem appears to be that it is difficult to connect very different organizational activities together through the use of computer systems with embedded organizational rules.

Chapter 3
Methods

From previous studies, we already know something about when manufacturing companies have problems using the full MRP2 model. Existing explanations of problems with using the MRP2 model, however, fail to account for these findings. Lee (1991) argues that existing explanations may be flawed because they are based on an inadequate *interpretive* understanding of how people in organizations see the world, and attribute meaning to their actions. In a series of three in-depth studies, I use a sequence of research activities recommended by Lee (1991) to revise the accepted interpretive understanding of when manufacturers are not able to use the full MRP2 model, and then revise and test a new positivist understanding of when they are not able to use the full MRP2 model.

This chapter describes the methodological choices made and procedures followed in these three studies. The first section introduces Lee's scheme for combining positivist and interpretive studies, a procedure that is used in this dissertation. The second section describes the grounded theory methods (Strauss, 1987) used in a study of how MRP2 professionals explain problems with using the full MRP2 model (Study 1). The third section describes the rationale for choosing FLEXCO, an electronics equipment manufacturer, as the site for Study 2 and Study 3, and provides relevant background information. The comparative case study methods (Ragin, 1994) used in Study 2 to test how well organizational differences between activities explained failures to use the full MRP2 model are described in section four. The last section discusses the participant-observation methods (Jorgensen, 1989) used in Study 3 to reveal the orientations people have towards reconciling the different uses of MRP2.

3.1 Combining Positivist and Interpretive Research

For my studies of MRP2, I use a research framework proposed by Lee (1991). Lee argues that existing explanations of any organizational activity may be flawed because they are based on an inadequate *interpretive* understanding of how the people within the organization see the world, and attribute meaning to their actions. Lee's framework is particularly appropriate when existing explanations make what appear to be unrealistic or oversimplified assumptions about people's subjective understandings and motivations. Explanations of failure to use the full MRP2 model solely based on people's "lack of discipline" or "lack of motivation to keep accurate data" do appear to be oversimplified and limited, considering the rich diversity of findings on organizational rule use.

Lee's framework provides a way of combining positivist and interpretive research that can illuminate and change these inadequate interpretive understandings. In this section, I will give Lee's definitions of positivist research and interpretive research, and the differences between them. Next, I will discuss Lee's claims about how positivist and interpretivist research can be integrated. Finally, I will show how my own study design uses Lee's framework.

Lee claims that there are two fundamentally different approaches to studying human organizations: the positivist approach, and the interpretive approach. The positivist approach uses the traditional scientific methods of the natural sciences. A scientific explanation is expressed in formal propositions, to which the rules of formal logic apply.

Formal propositions are converted to predictions about observable events (hypotheses) through the rules of hypothetico-deductive logic. Theoretical propositions must satisfy four requirements: falsifiability, logical consistency, relative explanatory power, and survival against continued testing. (Full definitions of each of these terms can be found in Lee, 1991; 344-347).

The interpretive approach, in contrast,

> maintains that the methods of natural science are inadequate to the study of social reality...Unlike atoms, molecules, and electrons, people create and attach their own meanings to the world around them and to the behavior they manifest in the world. (Lee, 1991; 347).

Interpretive research examines the subjective meanings that people assign to physical artifacts, human actions, and human institutions. The exact same physical object or objectively observable behavior can have different meanings for different people. These different meanings give rise to different behaviors. There is no agreement on the one best method for revealing subjective interpretations. Commonly used interpretive approaches include ethnography and hermeneutics (Lee, 1991; 347-350).

Positivist and interpretive approaches to organizational research are usually seen as mutually exclusive, irreconcilable research strategies. The two approaches are opposed to each other because their techniques for generating and verifying explanations are so different. Positivist approaches demand repeatable, objective measurements and strict controls; interpretive approaches require an explanation to provide a sensible account of human behavior—sensible to the researcher, the people being studied, or both. Lee's contribution is to argue that, while positivist and interpretive approaches each have their own distinct logics, results from one type of research can, and often should, be used to support or challenge the other.

Positivist and interpretive approaches are related because any positivist explanation of human behavior includes, implicitly or explicitly, an interpretive understanding of the meanings people use to guide their behavior. Subjective meanings are contained within positivist understandings because "a different reading or interpretation of what the organization means to the human subjects will lead to a different theoretical explanation for how the human subjects behave." (Lee, 1991; 352). Therefore, if a positivist explanation appears to be inadequate, Lee's framework tells us that one way to move forward is to identify the interpretive understanding built in to a positivist theory, and examine its adequacy. New interpretive explanations can lead directly to new positivist explanations. Any disconfirmation of positivist theory sheds doubt on the adequacy of its assumed interpretive explanation. Any inadequacies in an interpretive explanation also shed doubt on positivist explanations which use that interpretive understanding.

So, according to Lee's framework, there are three ways that organizational research can take place:

1) Use the standards of the positivist approach to generate and test explanations.
2) Use the standards of the interpretive approach to generate and test explanations.
3) Use one kind of explanation to inform the other, by either: a) identifying the interpretive understanding contained within a positivist explanation, and modifying or testing this interpretive understanding using the methods of the interpretive approach; or b) deriving a new positivist explanation from an interpretive understanding, and modifying or testing this positivist explanation using the methods of the positivist approach.

Lee's framework provides a way of combining positivist and interpretive research, if it is appropriate for the problem. Lee's framework does not demand it. "No claim is being made that all researchers must utilize every part of the framework." (Lee, 1991; 355). A single study may attempt to use all parts of his framework, beginning from either a suspect interpretive or positivist explanation, but this framework can also be used to combine different studies, by the same or different researchers (Lee, 1991; 363).

Lee, in his 1991 paper, provides an example of one sequence of research activities that illustrates his framework. The example he gives starts by identifying an inadequate interpretive understanding assumed by the literature, revises and improves the interpretive understanding, and then creates and tests a new positivist explanation based on the new interpretive understanding. His example (Lee, 1991; 356-360) goes through the following steps:

1) Identify the interpretive understanding assumed by the current literature.
2) Describe the traditionally held positivist understanding that follows from this interpretive understanding.
3) Review other research which disconfirms the traditionally held positivist understanding.
4) Revise the interpretive understanding.
5) Revise the positivist understanding, based on the revised interpretive understanding.
6) Test the revised positivist understanding.

I use these six steps in my research project, as described below:

1) Identify the interpretive understanding assumed by the current literature.

For the reasons discussed in Chapter 2, the prevailing explanations of problem using MRP2 poorly account for the failures to use parts of the full MRP2 model found by researchers. The dominant explanations can be broken down into Wight's (1984) categories of technical, basic data, and people explanations. According to traditional explanations, the full MRP2 model is not used because of computer malfunctions, the refusal of people to provide accurate data, or the refusal (or inability) of people to obey the formal MRP2 system.

All three of these explanations create a common interpretive story, characterized by the following elements. There is a group of (undifferentiated) people that work for a manufacturing organization. The manufacturing organization has a clear set of goals and interests which are best served by following the formal procedures built into the MRP2 system. Individuals have the choice of either using the formal system built into MRP2, or using an 'informal', illegitimate paper-based system left over from the days before MRP2. Individuals who choose to use the 'informal' system, and thus thwart the interests of the manufacturing firm as a whole, do so because the computer system is not available (equipment malfunction), because they lack the discipline to look beyond their immediate self-interest, or because they lack the education to understand the importance of ensuring data accuracy, or of following formal MRP2 procedures. The interpretive understanding implicit the MRP2 literature assumes that a failure to use part of the full MRP2 model is an inability to serve organizational goals, a poor understanding of organizational goals, or a choice to defy the organization for personal gain.

2) Describe the traditionally held positivist understanding that follows from this interpretive understanding.

This interpretive understanding sees the MRP2 use as an individual choice to pursue the interests of the manufacturing firm as a whole by using the technology, or to work against the smooth functioning of the organization. The positivist understanding that follows assumes that the objective forces that influence this choice to work with or against the organization are the most influential determinants of whether parts of the full MRP2 model are used. These objective forces include the availability of the appropriate tools, the amount of education about the importance of the formal system and data accuracy, and a lack of individual discipline.

3) Review other research which disconfirms the traditionally held positivist understanding.

The surveys of MRP2 use (Anderson et al, 1982; Cooper and Zmud, 1990; Sum and Yang, 1993) report that there are many implementation problems with MRP2, but that there is widespread adoption of a limited subset of MRP2 functionality. For the reasons discussed in Chapter 2, the traditionally held explanations of MRP2 failure are not consistent with this pattern of use. Therefore, the traditionally held explanations need to be revised.

4) Revise the interpretive understanding.

The inadequacies of accepted explanations of failures to use the full MRP2 model cast doubt on the adequacy of the interpretive understanding assumed by these explanations.

Study 1 created a new interpretive understanding by analyzing how MRP2 professionals themselves explained problems using parts of MRP2. By analyzing transcripts of professional MRP2 seminars, Study 1 revealed the importance of how people coped with the problems of coordinating very different organizational activities through MRP2 use. (Study 1 is described in section 3.2).

The interpretive understanding identified in Study 1—people's orientations towards reconciling the different uses of MRP2—was further refined in a later participant-observer study (Study 3, described in section 3.5).

5) Revise the positivist understanding, based on the revised interpretive understanding.

Based on the results of Study 1, I was able to create a new positivist understanding of why manufacturing firms fail to use parts of the full MRP2 model. According to this new explanation, parts of the full MRP2 model are not used when the organizational activities being linked through MRP2 use were too different, i.e., when they require too many people to take actions that are either contradictory or mutually exclusive. The organizational literature suggests many ways that organizational activities can differ. Based on the examples in Study 1, I chose three organizational explanations for further testing: differences in technical uncertainly between activities linked through MRP2 use, differences in outside legitimacy demands, and differences in group beliefs about legitimate behavior. Would these differences explain when parts of the full MRP2 model were not used?

6) Test the revised positivist understanding.

The revised positivist understanding was tested in Study 2 (as described in section 3.4). The results from Study 2 indicate that no one kind of organizational difference can account for all of the failures to use the full MRP2 model at one manufacturing company, but that differences between organizational activities do account for all major classes of failures to use the full MRP2 model. Trying to support too many organizational activities at once appears to be a promising explanation of why the simpler organizational models of MRP find widespread use, but the larger, all-encompassing organizational models of MRP2 tend to fall apart.

The sequence of studies is shown in Figure 2. My project began from the previous surveys of MRP2, which opened the question of why MRP2 use was widespread but limited. The interpretive study of MRP2 professional training (Study 1) challenged existing assumptions about MRP2 users, and opened up two new questions of its own: how do the differences between organizational activities coordinated through MRP2 make parts of the full MRP2 model more or less likely to be used, and what meanings do people have that guide their use of MRP2 in conflict-ridden situations? A positivist case study (Study 2) tested how well the differences between activities coordinated through MRP2 use accounted for failures to use the full MRP2 model, while a follow-on interpretive study (Study 3) refined the account of people's interpretive understandings of MRP2. The results of Study 2 and Study 3 opened the general problem of embedding organizational rules in computer systems—what I call the problem of ORBIS (Organizational Rule-Based Information Systems). Results from Study 2 and Study 3 were used to form a theory of computer systems as an organizational modeling process, as described in Chapter 7.

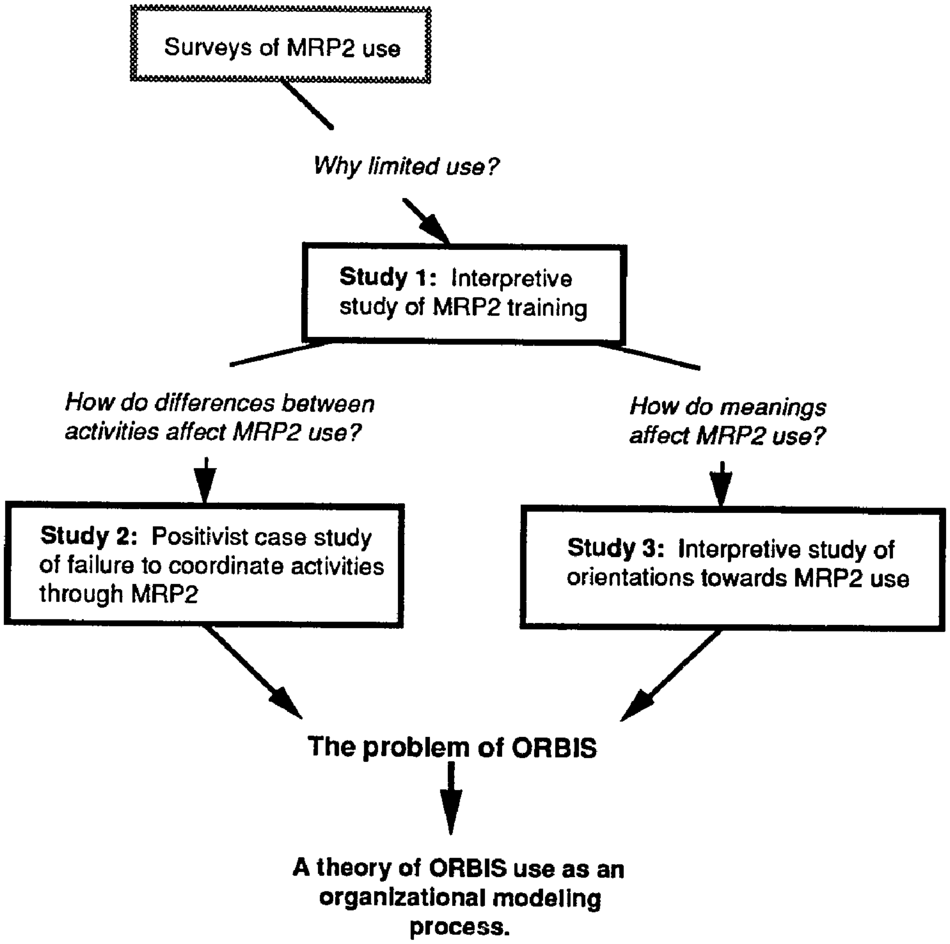

Figure 3.1: Overview of Research Project.

3.2 Revising the Interpretive Understanding (Study 1)

After identifying gaps in the existing explanations that can be traced to flawed interpretive understandings, Lee's framework suggests that the interpretive understanding should be revised. In this section, I describe a study of the explanations experienced MRP2 users give for why MRP2 use sometimes fails (Study 1). I discuss my data collection at a six week professional training seminar, and the process of data analysis through the use of the grounded theory approach (Strauss, 1987).

My purpose in studying the ways experienced MRP2 users explained MRP2 problems was to generate new explanations of failures to use the full MRP2 model that could be refined or tested in later studies. Over a six week period, I studied an MRP2 professional development seminar conducted by a local chapter of APICS, the American Production and Inventory Control Society. The seminar was designed to prepare early-to-mid-career manufacturing professionals for an APICS certification exam.

The format of the MRP2 seminar was six weekly discussion sessions, each lasting three hours. At each session, an industry consultant led a discussion of one aspect on MRP2, and answered questions from the audience. The industry consultants had an average of 16 years experience with MRP2 systems. The 17 participants in the seminar came from 11 different companies. Over half of the participants were buyers or planners—the primary users of MRP2 systems—with the balance coming from accounting, information systems, and manufacturing engineering backgrounds. Most of the participants had worked with MRP2 systems for at least a few years. Though the seminar participants spent almost half their time preparing for the content of the exam, the participants spent a significant amount of time swapping 'war stories', exchanging tips on MRP2, and good-naturedly complaining about MRP2 implementation difficulties.

My data for Study 1 consisted of full transcriptions of the six tape-recorded sessions. The seminar was open to anyone who paid the registration fee. I was introduced as a university researcher who was studying MRP2 use at the beginning of the seminar. I openly tape-recorded each session.

I used the grounded theory approach for analyzing the transcript data. Grounded theory is a style of qualitative analysis that provides a set of guidelines for generating and testing theory from non-numerical data (Strauss, 1987; 1). Grounded theory analysis consists of three types of activity: data collection, coding, and memoing. Textual data is collected from informants and archives. The data is coded by identifying meaningful categories that emerge as the researcher tries to account for the behavior described in the data. The researcher keeps track of existing codes, and the relations between them, by creating theoretical memos. The analysis evolves by deliberately seeking out new data collection opportunities that test whether the current set of categories and relationships does account for the behavior seen in the data; this constant testing of the evolving theory is known as theoretical sampling (Strauss, 1987; 21).

A grounded theory analysis moves between data collection, coding, memoing, and back to new data collection suggested by the current state of the theory. At the beginning, data is analyzed minutely in search of any potentially relevant categories; this stage is known as open coding. As the analysis progresses, more categories and relationships are identified. The explanatory power of these distinctions are tested through new theoretical sampling. A grounded theory analysis ends when the researcher identifies a core category (or perhaps two) that accounts for most of the variation in a pattern of behavior. A core category is able to integrate many of the categories and relationships identified in the analysis process—"the core category must be proven again and again by its prevalent relationship to other categories" (Strauss, 1987; 35). The analysts tries to achieve a point of theoretical saturation, when additional analysis no longer contributes anything new to the core categories. (Identifying the core category, and thus bringing the analysis to a conclusion, is one of the most difficult aspects of grounded theory work. Strauss (1987; 36) mentions several criteria for judging whether a category is truly a core category.)

As an example of grounded theory analysis, consider this excerpt from the first session transcript:

> ...and we've got to manage with the formal system. That's what we use it for. We've got to be trained, and purchasing's got to do their thing on time, production control's got to do their thing on time. The shop's got to follow the priorities. There's got to be **discipline**. People aren't doing their jobs, get rid of them! Let them work for somebody else. If you don't have **discipline**, you might as well not turn the system on.
>
> (APICS1.11)

The seminar participants are talking about a failure to use MRP2. The initial study question was, how do MRP2 professionals explain why parts of the full MRP2 model are not used? In the open coding stage, all of the underlined items were coded as potentially relevant categories. The first sentence suggested that a difference between 'managing through the formal system' and 'managing through the informal system' might be a significant explanation of failures to use the full MRP2 model. 'Educated about MRP2' vs. 'not educated' was opened as another potential category. The phrase "do their thing on time" opened two categories: 'competence' and 'time horizons' ('short' vs. 'long'). The bolded item, "discipline", was identified in open coding and quickly emerged as a potential core category.

Theoretical memos are produced for each of the identified categories that the researcher considers promising for further development. These memos raise new questions that can be tested on other descriptions of MRP2 use problems in the transcripts. For example, the category 'educated' raised the questions: are there accounts of problems using the full MRP2 model in which the users were educated? Are there accounts of successful MRP2 use where the users were not educated? Because the other accounts rarely mentioned 'education', and because some examples showed that 'education' did not guarantee successful use, 'education' was dropped as a potential core category. A conjecture about the importance of 'discipline' for explaining failures to use parts of the full MRP2 model, however, was tentatively confirmed by other accounts in the data. Though there is no precise method for counting the number of accounts in the transcripts, there were between approximately 90 to 110 accounts of problems using parts of the full MRP2 model.

In further theoretical memos, the concept of 'discipline' was linked to another concept, 'the desire for flexibility', that emerged from another transcript episode. This larger concept, 'maintaining a reasonable balance between discipline and flexibility', led to conjectures that explained more of the episodes in the transcript data than either 'discipline' or 'desire for flexibility' alone. The larger concept also successfully integrated many of the other categories already identified in the analysis: 'the formal system' (tied to maintaining discipline), 'competence' (tied to a desire for effectiveness that sometimes meant being flexible with the formal system), and 'time horizons' (the pull of flexibility becomes stronger as time horizons become shorter). By the end of the analysis, the concept 'maintaining a reasonable balance between discipline and flexibility' was subsumed another larger category, 'reconciling the different uses of MRP2', that emerged as a core category of the study.

3.3 Selecting the FLEXCO Case

Study 2 and Study 3 took place at a manufacturing firm in the Western United States which I call FLEXCO. My criteria for choosing FLEXCO as the study site are listed in this section, followed by some background information about FLEXCO and its organization.

My criteria for selecting a manufacturer to study were: the company must fit the pattern of MRP2 use seen in the literature; the company must be a successful manufacturer, broadly defined; and the company must be willing to have a researcher present for an extended period of time. Finding a case that matched the larger pattern of MRP2 use helps ensure that the findings will be of wider interest. Studying a successful manufacturer protects against the risk that failures to use parts of MRP2 would be attributed to the company's incompetence. Finally, the willingness of the company to officially and openly participate in the study would, I felt, ensure that all of the relevant functional areas would be encouraged to participate in a way that a covert study might not have allowed.

FLEXCO fits these three criteria. At the time of the study, FLEXCO used a three year old version of a market-leading MRP2 system. The MRP2 system supported around 80 direct users, and ran on a VAX minicomputer platform. FLEXCO's use of MRP2 matched the larger pattern commonly found in the literature: a limited subset of MRP2 functionality (most of the MRP level) was used heavily, but many parts of the full MRP2 model were not. Many of the functions of closed-loop MRP, or MRP2, were handled through visual production systems, paper-based systems, or decentralized computing platforms using general-purpose applications (e.g., an EXCEL spreadsheet on a Macintosh).

FLEXCO was also a successful manufacturer. FLEXCO was a US subsidiary of a Japanese-owned multinational corporation specializing in electronics. Despite relying on products that were most often manufactured in lower-wage East Asian countries, such as computer keyboards and mice, FLEXCO reported a solid profit during the previous two years. FLEXCO's innovative products had been praised in the trade journals. But, more importantly, FLEXCO was celebrated for its manufacturing processes. FLEXCO was featured in an SME (Society for Manufacturing Engineers) video series on leading-edge shop floor management practice, and was cited in Suzaki's *The New Shop Floor Management* (1992). In the year before the study, FLEXCO had won the highest supplier quality rating from the "big three" US auto makers, and had been named a "supplier of the year" by Canon and Xerox. FLEXCO was also one of the first manufacturers in its area to receive full ISO9001 certification.

FLEXCO was also willing to have a researcher present for an eight month period. FLEXCO prided itself on its willingness to be open to visitors from academia and industry (even competitors). Their official explanation was that they learned about outside practices from these exchanges, and that the relationships formed might lead to more business for FLEXCO in the future.

Figure 3.2 gives a pictorial overview of FLEXCO. FLEXCO is a medium-sized manufacturer of computer peripherals and automotive electronic equipment. FLEXCO has approximately 800 employees, 400 of whom are temporary factory workers. 20 different assembly lines manufacture 30 different end products (including computer keyboards, mice, trackballs, and automobile switches). The products are assembled repetitively, but are made to customer orders. FLEXCO's yearly revenues are approximately $150 million.

FLEXCO is one manufacturing division of a large, Japanese-owned electronics firm. The FLEXCO US headquarters, home to FLEXCO's sales and marketing staff, is located 500 miles away from FLEXCO. Other FLEXCO divisions are located in Mexico, the Eastern US, Europe, and Japan.

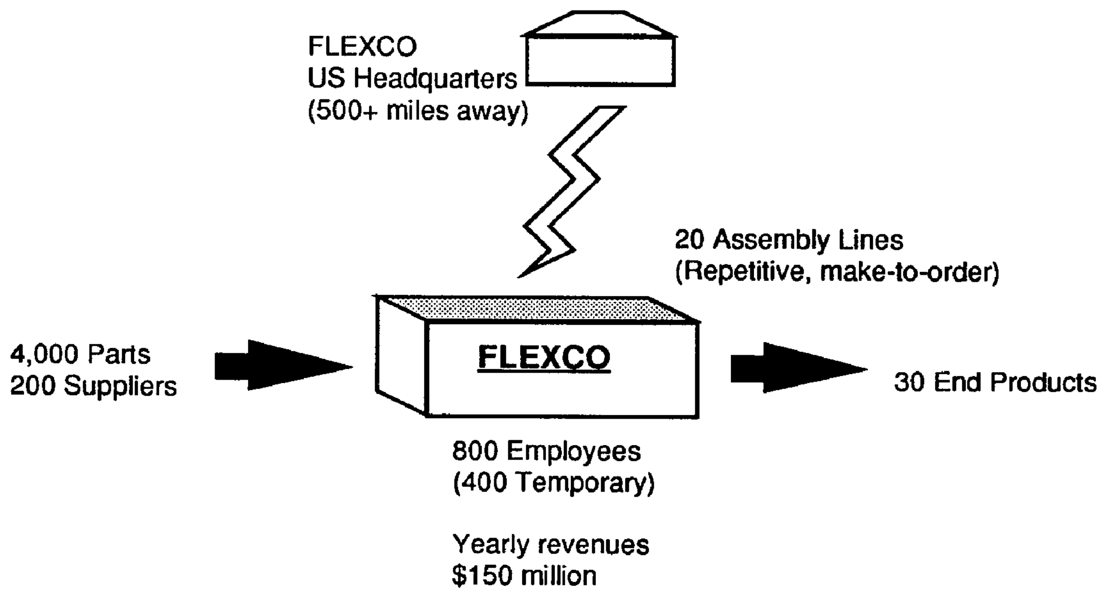

Figure 3.2: FLEXCO Overview

I call the company FLEXCO because of their strategy for surviving in a relatively high-cost manufacturing area: flexibility. FLEXCO is very flexible about the type and volume of products it makes for its customers. In exchange for a higher cost, FLEXCO's customers demand large variations in production volume (sometimes from tens of thousands of keyboard per month to zero), quick transitions between products, high quality design work in response to engineering changes, and very high manufacturing quality. During my study, I once saw a new keyboard assembly line, with 12 manufacturing operations and robotics, built and working in less than a week. FLEXCO has to be flexible. At the beginning of fiscal year 1993, FLEXCO's General Manager announced that half of their revenues that year would come from products that were not yet in production.

The work groups listed in Table 3 were the direct or indirect users of the MRP2 system.

Table 3.1: Work Groups Using MRP2 at FLEXCO

Buyer/Planners
Design Engineering
Finance
Human Resources
Information Systems
Manufacturing - Auto Products
Manufacturing - Computer Products
Manufacturing - Plastics
Quality Engineering
Sales/Marketing (off-site at FLEXCO US Headquarters)
Upper Management
Warehouse/Material Coordinators

3.4 Revising and Testing the Positivist Understanding (Study 2)

Lee's framework suggests that a new interpretive understanding can form the basis of a new positivist explanation of failures to use the full MRP2 model. In Study 2, I examine whether the differences between activities coordinated through MRP2 use account for failures to use the full MRP2 model. Study 2 uses the logic of a comparative case study to investigate this new explanation. Data collection for Study 2 included archival data, unobtrusive systems measures, and semi-structured interviews with representatives of the 12 work groups most closely involved with MRP2. Data analysis used the comparative analysis technique described by Ragin (1994), which compared three theories of how organizational activities can be characterized as different.

Study 1 identified a potentially new explanation for the failure to use parts of the full MRP2 model: the MRP2 model tries to coordinate organizational activities that are too different. Study 2 uses a comparative case study research model to examine how well three theories of organizational differences between activities account for failures to use the full MRP2 model. In-depth case study research is used because this investigation fits Yin's (1984) criteria for when to use a case study: the theory is new or emerging, the study investigates how and why kinds of questions (rather than how many), the researcher has low control over behavioral events, and the events are contemporary (rather than historical).

Study 2 used a comparative research logic (Ragin, 1994). The comparative model examines patterns of similarities and differences across a moderate number of examples (Ragin, 1994; 105). In Study 2, 48 examples of information use that were failures to use the full "Class A" MRP2 model (as first described by Wight, 1984) were identified from the interview data. In comparative research, the examples are coded (as true/false, or present/absent) with respect to theoretical categories. The theoretical categories are defined before the beginning of the study. The pattern of examples is then reduced to the simplest logical form that accounts for the data, using the laws of boolean algebra.

Study 2 investigated how well three competing organizational theories explained failures to use the full MRP2 model at FLEXCO. Each of the theories gives a competing explanation of how organizational activities can clash—clashes that lead to use problems as the MRP2 model is extended to support more organizational activities. The three theories used are structural contingency theory, institutional theory, and social rule system theory. The three theories were chosen to cover both rational and natural theories of organizations (Scott, 1992), and both open (external) and closed (internal) theories or organizations (Scott, 1992).

The implications of structural contingency theory for detailed information sharing have already been worked out in detail in Goodhue et al (1992). According to this theory, the technical demands of tasks should be aligned with the appropriate amount of information processing capability. Tasks with different technical demands that are tightly linked, such as long-term planning and daily scheduling, would experience more problems than linking tasks with similar technical demands. *Conjecture 1 (Structural Contingency Theory): the use of MRP2 information to jointly coordinate separate activities is less likely between activities with different levels of technical uncertainty.*

Similarly, we can use institutional theory (Powell and DiMaggio, 1991; Scott, 1992) to derive a theory of detailed information sharing between activities from a natural, rather than rational, perspective on organizations. According to this theory, organizations adopt structures and practices, including information technology, on the basis of conformance to rationalized myths that preserve an organization's legitimacy in the eyes of powerful external actors. The external legitimacy demands may come in the form of government regulations, safety regulations, professional codes of practices, and general laws that must be conformed to. Activities that face strong demands of this kind are said to operate in environments with strong degrees of collective external organization. *Conjecture 2 (Institutional Theory): the use of MRP2 information to jointly coordinate separate activities is less likely between activities with different but strong degrees of collective external organization (institutionalization).*

In contrast to the very external, open focus of the two theories mentioned above, social rule systems theory (SRST) (Burns and Flam, 1987) concentrates on the different schemes internal groups have for defining what is legitimate behavior. According to SRST, a major source of dynamic or contradiction in organizations is the problem of "insufficient exclusivity": multiple social rule systems can be legitimately applied to the same concrete action domain. Groups may disagree over how people should behave in particular situations. SRST theorizes that there are active political struggles over the maintenance and change of social rule systems, in contrast to institutional theory's emphasis on taken-forgranted beliefs. *Conjecture 3 (Social Rule System Theory): the use of MRP2 information to jointly coordinate separate activities is less likely between activities governed by conflicting social rule systems.*

Data collection for Study 2 consisted of two parts: identifying failures to use the full MRP2 model, and identifying whether significant organizational differences were present (as predicted by the three conjectures). Data for identifying failures to use the full MRP2 model came from two sources. First, I used the MRP2 system itself. I had full, unrestricted access to the MRP2 databases, which allowed me to look and see which MRP2 modules were being used. I also had access to company records on MRP2 report distribution. Second, I was able to ask users in semi-structured interviews whether, and to what extent, aspects of the full MRP2 model were in use at FLEXCO. Triangulating between the two kinds of data led to a list of 48 specific failures to use the full MRP2 model.

Semi-structured interviews were used to probe whether the organizational differences predicted in conjectures one, two, and three were present, in addition to MRP2 use information. My interview strategy was to perform at least two in-depth interviews (60-120 minutes in length) with a key informant from each of the 12 work groups. This goal was achieved or exceeded for all work groups except one (Plastics Manufacturing). My semi-structured interview protocol was composed of prompts that could be used in any order. Prompts for 'how' and 'what' questions (as opposed to 'why' questions), using simple and positive language, allow respondents to tell their story in their own terms (McCracken, 1988). I took notes by hand, rather than tape recording, at the insistence of my initial contacts at FLEXCO.[1]

[1]Despite the greater accuracy of tape recordings, some methodologists recommend handwritten notes over tape recordings (e.g., Lincoln and Guba, 1985; 272) because of their unobtrusiveness.

Background and Personal Information
prompt "How long have you worked here?"
prompt "Where else have you worked?"
prompt "What do you do (most of the time)?"
prompt "What do you really like about your job?"

Use of Production Planning and Control Information
prompt "What information do you use from the (MRP) system? From reports?"
prompt "What information do you use from your PCs?"
prompt "What other information do you use?"
prompt "How much do you use this information? How easy is it to use?"

Possible Organizational Reasons for Use Problems
prompt "How complicated is this activity (vs. another)?"
prompt "How often does this activity change (vs. another)?"
prompt "Is this information mostly for people outside of FLEXCO?"
prompt "How should this information be used by your group? By others?"

Figure 3.3: Semi-Structured Interview Protocol

Each of the three competing theories suggests its own data collection strategy. For each theory, I strived to triangulate between the interview data and at least one other data collection method (as suggested by Marshall and Rossman, 1989).

To evaluate conjecture one, I collected interview data on how two or more activities not coordinated through MRP2 use (for example, production scheduling and quality evaluation) differed in terms of technical uncertainty. Technical uncertainty has two aspects: frequency of change, and complexity (Scott, 1992). Two prompts from the interview protocol looked for differences in technical uncertainty between activities. In addition, I was able to collect additional data on change and complexity differences from the MRP2 system. For directly comparable activities, such as different manufacturing processes, the MRP2 system yielded data on the number of schedule changes (a measure of change frequency), and the number of parts used (a measure of complexity). Using these data sources, I coded the activities not coordinated through MRP2 as having 'different' levels of technical uncertainty if all the relevant groups consistently perceived a significant difference, and a noticeable difference could be seen in the systems data. Otherwise, the activities were coded as 'not different'.

To evaluate conjecture two, I collected interview data on whether informants perceived a difference in the external legitimacy demands faced by activities. These outside legitimacy demands could come from government agencies, customers, professional organizations, or general laws. The interview data was supplemented by company newsletter archives for the three years preceding the study. Company newsletters would sometimes mention, for example, that a certain kind of information use was initiated because of an external legitimacy demand. Using these data sources, I coded the activities not coordinated through MRP2 as facing 'different' external legitimacy demands if all the relevant groups consistently perceived a significant difference, and there was either support for, or no information about, a difference in the newsletter archives. Otherwise, activities were coded as 'not different' along this dimension.

To evaluate conjecture three, I collected interview data on what different groups perceived to be legitimate uses of MRP2 information. This data is the most questionable because of its sensitive nature. It was also the most difficult to confirm through other sources. However, by examining the interview transcripts for complaints about illegitimate uses of MRP2 by other groups (which were quite frequent, and followed regular patterns), I could code activities as having 'different' social rule systems if the interview data contained a number of legitimacy complaints about MRP2 use from all the groups not linked through MRP2.

After the data collection and coding, the data was analyzed by constructing a truth table, as suggested by Ragin (1994). The table consisted of three columns—one column for each of the three competing theories. Each row of the table represented one example of a failure to use the full MRP2 model at FLEXCO. In each row, a '1' would represent a difference between linked activities as predicted by one of the three theories. A '0' would represent no difference.

Reduced to a truth table, the data was analyzed by simplifying the table through the laws of boolean algebra. This procedures is familiar to computer scientists. The boolean table can be simplified by hand (Ragin, 1994; 123-129), or by using commonly available, public domain computer programs.[2] The logical formula that emerges is the result of the analysis, showing a theoretical pattern that accounts for the data.

The use of comparative methods results in a description of the patterns of causal factors and consequences seen in the data (Ragin, 1994). The MIS case study methodology described by Lee (1989) provides a stronger result, in the sense that one theory emerges as having greater explanatory power than the others. At the beginning of Study 2, I tried to use Lee's MIS case study methodology. I had to abandon it, however, when it became clear that all three theories were needed to account for the MRP2 uses found in the data—no one theory was able to consistently refute the others. The results from the comparative case study are not as definitive in comparing the explanatory power of the three theories, but the comparative case study does strongly suggest that organizational differences play a role in failures to use the full MRP2 model.

[2]I used DigSimp 2.00, a public-domain program for Macintosh computers available at well-known archive sites.

3.5 Further Revising the Interpretive Understanding through Participant-Observation (Study 3)

Study 1 suggested that people's orientations towards reconciling the different uses of MRP2 were critically important for understanding when parts of the full MRP2 model were used. Study 1 made a first attempt at describing people's orientations towards MRP2 use. However, Study 1 was limited. The theoretical categories identified by Study 1 could not be completely investigated in the limited transcript data. The data itself was taken from a seminar, where people gave accounts of MRP2 use outside of their normal working environments. To obtain a better understanding of people's orientations towards MRP2 in real working environments, I decided to further revise and refine the new interpretive understanding by engaging in a five month participant-observer study at FLEXCO.

The participant-observer method has been used by fields such as anthropology to study the little known, subtle, and sometimes deliberately hidden meanings held by people (Jorgensen, 1989). Because failures to use parts of the full MRP2 model are often considered illegitimate, methods such as participant-observation provide one of the few ways to see and understand this behavior. By assuming a role in an unfamiliar culture, and participating in their common activities, the researcher becomes the research instrument. Participating in the culture allows the researcher to create explanations that make sense of behavior that appears unreasonable to outsiders. Creating sensible explanations of meanings that account for previously unexplainable behavior is the main validity test of interpretive research (Lee, 1991).

There are many issues involved in the construction of a participant-observer study (Jorgensen, 1989): how entry to the research site is obtained, the role constructed for the participant-observer, the dependability of the data collection, and the data analysis process.

After completing Study 2 at FLEXCO (a two month study which consisted mostly of interviews), I sent a proposal to my initial FLEXCO contact (a project manager not involved in Study 2) for a longer-term participant-observer study. I proposed that, in exchange for 6 months of access to FLEXCO (10-15 hours per week), I would work in FLEXCO's Information Systems department for free on a project of their own choosing. FLEXCO upper management agreed to these conditions. I received cubicle space in the Information Systems department, an employee badge, and my own MRP2 terminal. The project we agreed on was an effort to track supplier performance through the MRP2 system (in terms of on-time delivery, incoming inspection quality, and shop-floor defects). This project had lingered for the past three years with no progress. Management did not understand why the system couldn't be done, Information Systems did not have the knowledge or motivation to figure out why it wasn't working, and FLEXCO's most recent ISO9001 audit demanded that a supplier performance system be in place.

The role a researcher constructs in a participant-observation study can vary from complete outsider to complete insider. The role I constructed, "a researcher from UCI working on a special computer project for FLEXCO," leans more towards an outsider role. I chose this role because I needed access to all of the work groups using MRP2. I sought to identify myself as someone working for FLEXCO, but I did not want to be seen as a full member of the Information Systems group, or any one work group.

The dependability of participant-observer data collection rests on at least three factors: multiple sources of evidence, extended rather than limited access, and a careful description of data collection procedures. Because I had developed first-name relationships with 11 key informants from the 12 different work groups, I had a substantial network in place that allowed me to collect data from multiple viewpoints. My research access lasted for a six month period, usually three days a week for 4-5 hours per day. There was no strict timeline; I was able to terminate the study when I felt it was appropriate. My data collection began with the interview transcripts from Study 2. Analysis of the meanings contained in the interview data (rather than the differences between activities) served as the starting point for more casual conversations with my contacts. I stopped by their desks, took people out to lunch, sat in on meetings, and observed as people came to the Information Systems area for help. There was no tape-recording of these sessions. I wrote notes on paper immediately after the encounter (except in meetings, where I was able to take notes openly). Most of these encounter notes were only one or two paragraphs. My systems project also gave me access to many working sessions and meetings in my role as a computer analyst.

Jorgensen (1989) recommends grounded theory as one method for analyzing participant-observer data. I used grounded theory for analyzing the data collected in Study 3. The grounded theory method is described in section 3.2.

Chapter 4

Study 1: Interpretations of Failure in MRP2 Professional Training

As a first attempt to generate new explanations of why parts of the full MRP2 model are not used, I studied a group of experienced MRP2 users in a professional development seminar. Once a week, for a six week period, an industry consultant with an average of 16 years worth of MRP2 experience would lead a group of 17 experienced MRP2 users. (The details of this study are presented in Chapter 3.2). As I listened to their "war stories" of the realities of MRP2 use, my goal was to analyze their explanations of why companies sometimes failed to use the full MRP2 model. Why did these professionals think problems happened?

I found that their explicit explanations of MRP2 problems—when they said "MRP2 fails because of X"—were traditional: incompetent or uneducated people, and inaccurate data. However, when they talked about actual examples of MRP2 use problems, different themes emerged. By analyzing their discussions, I was able to generate two different kinds of explanations of failures to use the full MRP2 model.

First, problems were caused by the differences, or conflicts, between activities coordinated through MRP2 use. In the process of using systems that coordinate multiple activities, these experienced MRP2 users cited numerous examples of both direct clashes (where the activities or functional areas in conflict are explicitly named) and indirect clashes (where one or more of the conflicting parties are unnamed) brought about by MRP2 use. Often, they interpreted these clashes as incentive differences.

Second, problems with using the full MRP2 model were caused by the orientations people had towards reconciling the different uses of MRP2. In their accounts, people would see systems use (for example, as "protection") in ways that would lead to MRP2 breakdowns. I identified two different kinds of tensions in their explanations. One was a tension between the need for "discipline" and the need for "flexibility" in their relationship towards the system. Another was a tension between a desire for "commitment" from others and "protection" for yourself through MRP2 use.

Identifying these two kinds of interpretations in their accounts of why parts of the full MRP2 model are not used—differences between activities, and orientations towards use—formed the basis of a new positivist explanation tested in Study 2, and a new interpretivist explanation examined in Study 3.

4.1 Explanations of MRP2 Use Problems: Explicit and Implicit

Experienced MRP2 users give very different explicit reasons for failures to use the full MRP2 model than the reasons implicit in their stories of failure. When the MRP2 users say explicitly "MRP2 fails because of X", their explanations followed Wight's traditional categories: incompetent or uneducated people, and inaccurate data. The overall story they told was one of individual choice—either use MRP2 properly, and serve the interests of the company, or refuse MRP2 for personal gain. When they talked of MRP2 in the abstract, they spoke of the individual versus the good of the whole company. (See Figure 4.1).

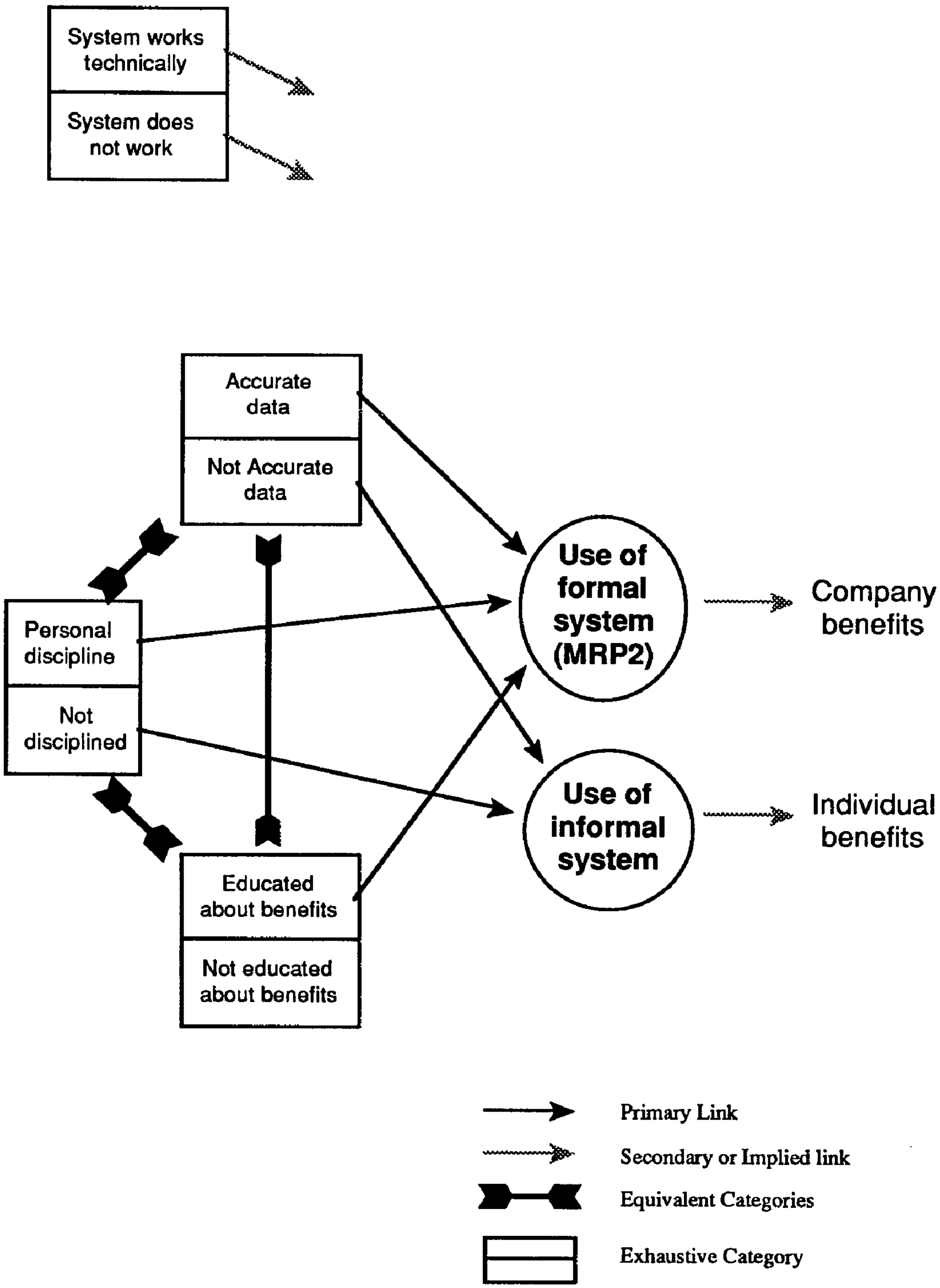

Figure 4.1: Explicit Accounts of MRP2 Use Problems in the APICS Seminars

The MRP2 users, in their explicit accounts, made four crucial distinctions that separated poor from successful use of parts of the full MRP2 model. The first was a distinction between a system that 'works technically' and a system that 'does not work'. Technical adequacy is one of Wight's (1984) three traditional factors for MRP2 success. While technical adequacy was essential, in their view, the MRP2 professionals felt that technical problems were not the most pressing. They described the technical logic as "simple" or "stupid"—a technology that should be easy to use:

> This is a computer-based system. These days, they've got very good software out there that really works, and you should test it first because there's some of them have serious flaws in it. but you've got to test it. I mean, if you say you can't make MRP work, that means you can't subtract six from ten to get four, and three from four to get one, right? Because that's all MRP is. It's just subtraction.
>
> (APICS 1.11)[1]

The three other distinctions the MRP2 users considered crucial were 'discipline', 'accuracy', and 'education'. In their accounts, 'discipline', 'accuracy', and 'education' were seen as equivalent. A high amount of personal discipline was always associated with a high education level about the benefits of MRP2 for the rest of the company, and with a high level of data accuracy. The importance of 'accuracy' for MRP2 use was clear:

> The accuracy of the bill of materials is critical. If you have bill of materials that aren't right, when you run the MRP the system's going to order the wrong material, and the wrong usage. It's only doing what you tell it.
>
> (APICS 4.12)

> If your data isn't accurate, you can have, you can spend a billion dollars. You can have the best software available. You can have the best hardware available. It can be, you know, lightning speed stuff. But if the data isn't right, it's not going to do you a dang bit of good.
>
> (APICS 4.10)

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[1]The quotes from the APICS transcript data are taken from the session leader, unless otherwise noted. The reference number is composed of the session number (one through six) followed by the page number of the transcript.

Data 'accuracy', however, depends on disciplined and properly trained people using the system, according to their accounts. Otherwise, a good system would be ruined by irresponsible behavior:

> All the benefits you could possibly dream of are there. The system works. But if you don't have a commitment, you don't have trained people, you don't have a system of accurate inventory records, and so forth, you want to keep jacking around the schedule promising the moon to everybody, fine. Not going to work.
>
> (APICS 1.11)

'Accuracy' is closely related to 'discipline' in these accounts. 'Discipline' implies that a person or company is in control of themselves and their work, and that they continue to work within the framework of the formal MRP2 system. If a person is too lazy, or too afraid of looking like a poor performer, to delete from the system an incoming shipment that never arrived, they lack 'discipline':

> But MRP's stupid, you see. This whole thing, it doesn't think, it just performs mathematical calculations. Pretty soon, if you have enough material that past due in the short order quantities, it adds up to quite a bit. So MRP says, yeah, those things are coming in. Doesn't care if they're 18 months old. And I've been in companies that had purchase orders that were past due 18 months [*groans from the audience*], and the system still assumes that they're coming in. Right? So there we see an example of where purchasing is out of control, the management team is out of control, and that's one of the many reasons why MRP systems don't work. They work. The math is pure and simple, logical, it's the disciplines that are in place.
>
> (APICS 1.2)

A lack of 'discipline' is tied to a lack of 'education' about the benefits of using the MRP2 system. 'Education' ensures that workers know why 'discipline' is important for the good of the company:

> I mean, if there's a problem, it's probably because they aren't aware of the discipline that needs to be there. The problem that it's causing in other areas, OK? It's training and education. And also to make sure that they

> understand that if there's a 3 o'clock cutoff for everything to be input, 3 o'clock's the cutoff. It's got to happen.
>
> (APICS 4.18)

'Discipline' and 'education' are consistently seen as leading to successful use of the full MRP2 model:

> A truly effective MRP system is when everyone in the organization who is directly involved understands the whole system. You know, there's different levels of users in MRP? Class A is like a really good one. There's very few good users of MRP in the United States. Very few. And why is it? Lack of discipline. Poor systems and procedures. Lack of education.
>
> (APICS 4.18)

Good 'discipline', 'accuracy', and 'education' lead to the use of the formal MRP2 system, according to their explicit accounts. Use of the formal MRP2 system, according to these explanations, is good. MRP2 systems work well for manufacturing companies, and using MRP2 to the fullest extent is in the best interests of the company. Despite the fact that many companies have severe implementation problems with these systems, and most companies only use a partial subset of MRP2 functionality, an inability to use MRP2 properly is seen as a personal failing in these accounts:

> You've got to manage with the formal system. You know, I've heard managers, presidents say well, we can't manage with an MRP system. We couldn't get MRP to work. Any person that makes that statement is raising a flag and says, should be printed on it, says I am an incompetent manager [*ooohs from the audience*]. The president that says he can't make MRP work should not be with that company. He is a lousy manager. Because of the fact that I've put these systems in several places, and they've been successful.
>
> (APICS 1.10)

In this section, we have seen the explanations that experienced MRP2 users give for failures to use the full MRP2 model. The important distinctions in their explanations—'discipline', 'education', 'accuracy'—match the traditional understanding of MRP2 use problems. Their explicit reasons for failures to use the full MRP2 model create a conflict between the clear organizational benefit of using the formal MRP2 system, and the possibilities for irresponsible or ineffective behavior caused by undisciplined or uneducated individuals.

4.2 Differences Between Activities: Direct and Indirect Clashes in MRP2

Experienced MRP2 users may say that problems with using the full MRP2 model are caused by individuals with poor discipline and education, but their specific examples of problems point to a different kind of explanation. By analyzing the transcript data for similarities in the way they discussed specific MRP2 problems, we can see a very different interpretation of why companies sometimes fail to use parts of the full MRP2 model.

The results of my data analysis, as summarized in Figure 4.2, provide one way of accounting for this difference. MRP2 systems were seen by the MRP2 users as connecting together many different organizational activities—from scheduling, purchasing, and receiving, to accounting, quality, and engineering change control. Their perception is consistent with Wight's (1984) description of MRP2 as "one set of numbers" to run the business. However, their accounts of problems using the full MRP2 model attribute many of the problems to conflicts between groups trying to perform different activities through the same MRP2 system. Further, many of the explanations that the professionals give for their behavior, from maintaining flexibility to seeking protection from others, can be seen as attempts to reconcile these partially conflicting uses of MRP2. Their accounts of MRP2 problems as partially conflicting uses, and as attempts to reconcile these partially conflicting uses, form the two core categories of my grounded theory analysis.

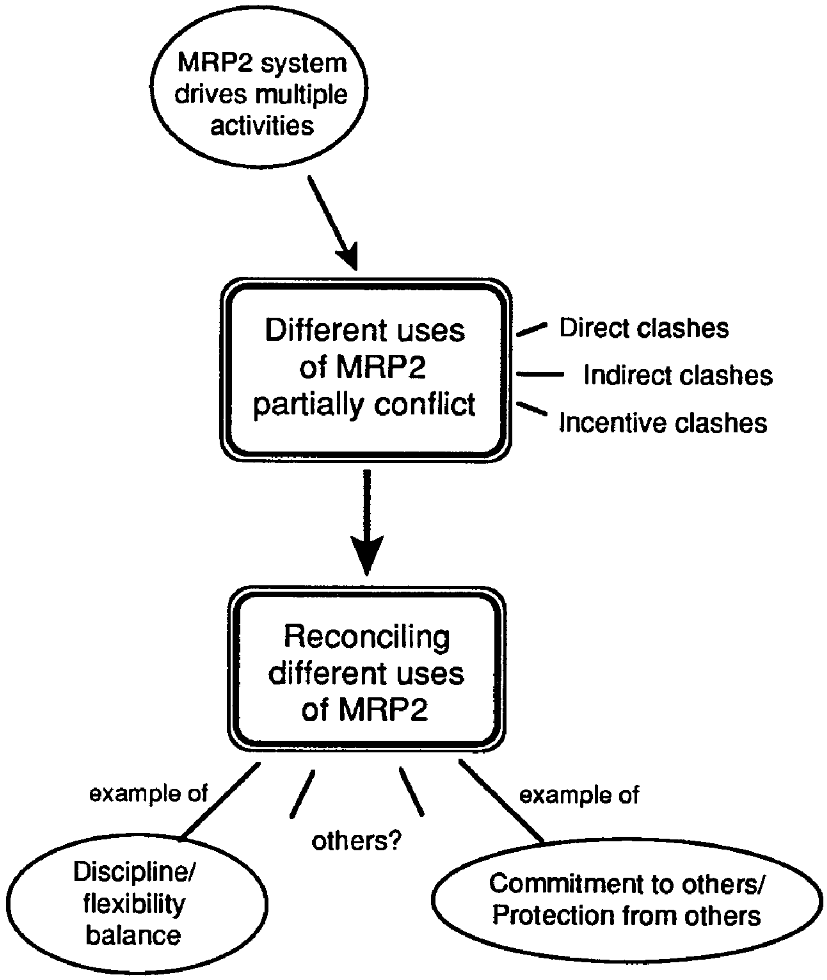

Figure 4.2: Explanations of Poor MRP2 Use

The key difference between the accounts of failures to use the full MRP2 model implicit in their examples, and their traditional explanations, is the presence of new kinds of conflict. Rather than the conflict between the individual and the clear interests of the organization, they attribute MRP2 use problems to conflicts between groups performing different activities within the organization, and to conflicts between these groups and the outside world. This basic realization makes defining good MRP2 use much more complicated for the MRP2 user. Presumably planners, design engineers, and manufacturing supervisors are all doing things that are, in some way, essential to the organization. Yet their perceived information needs sometimes collide. What these experienced MRP2 users are doing, in practice, is engaging in a different kind or organizational analysis, where goals and interests within an organization can be in conflict. In theoretical terms, they are using a natural systems model rather than a rational systems model of organizations (Scott, 1992). Or, according to Kling's (1980) paradigms of computing impacts research, they are using a segmented institutionalist model rather than a systems rationalist model of organizations.

The MRP2 users understand MRP2 as a computer system that links many different activities together, and should. Mimicking Wight's (1984) description of MRP2 as providing one set of numbers to run a business, they describe MRP2 as an integrated system:

> MRP2, this is true, but what it's doing is we're interfacing with the customer service and sales order entry, and accounting. Why? To accounts payable, accounts receivable, manufacturing costs, and so forth. All through a single software package. We're dealing with managing the business now with one set of data. All right, I see these people buying PCs and this guy's doing this on a PC, and that guy's doing a PC, accounting's doing something else. They're shooting themselves in the foot. You need an integrated system that everybody's using to run the business.
>
> (APICS 1.11)

The professionals consistently advocate using MRP2 as the one and only system for the entire organization's needs:

> Within a company, I highly recommend not having any more than one software package throughout the organization, as far as anything having to do with the full cycle. Accounting can't be on a separate package, you know. Scheduling can't be, whatever it is. You've got to talk about MRP, one package.
>
> (APICS 4.22)

But while their enthusiasm for an integrated information system matches Wight's, their accounts show an appreciation for the difficulties of providing one organizational model through a single system. An MRP2 system contains many different rules and parameters that link together different activities. For example, the models of how parts are routed through the factory help determine when manufacturing and purchasing activities should take place:

> Are the standards on your routings accurate? When it says you can produce 100 pieces an hour, can you really produce 100 pieces an hour, or can you really produce 50 pieces an hour, or can you really produce 200 pieces an hour? That's important, because all this other data is built up on those standards.
>
> (APICS 5.3)

The MRP2 professionals have an appreciation for what they see as the danger of integrated systems: the effects that small changes in one area can have on the entire system. This is interpreted as one activity "driving" another, or "cascading" into another:

> So, master schedule changes can be deadly occurrences. And what they do when you pump them through an MRP system, is it makes the MRP nervous. Makes the MRP go up and down, up and down. And what happens is it cascades through everything. So you're going to see that everywhere. Changing, up and down.
>
> (APICS 3.6)

> But when you put that scrap percentage in, you also have to recognize it's going to cascade through the entire MRP process. So you will be ordering more of everything.
>
> (APICS 3.7)

The interconnections due to MRP2 use are seen as creating new demands on the relationships between groups:

> So the master production schedule has to be signed off by the senior management team because it's driving inventory plans, capacity requirements, and so forth, over a planning horizon.
>
> (APICS 1.5)

The MRP2 users talk openly about the possible conflicts that arise when the MRP2 system "has to know everything that's going on," even if their explicit accounts of how to deal with the problems are, again, traditional:

> Because certain people who don't take ownership for the entire system are going to go around it, OK? But within your companies, with an MRP system, it's not the materials people. It's not the accounting people. It's the entire organization that has to understand the benefit from an MRP system. And if everyone really understands the benefit, and it's consistently enforced, and communicated that it really is a benefit, and everyone needs to be involved. Engineers can't talk directly without telling people so that the computer's updated. That's all. If you need to change something, you've got to tell us. The computer has to know everything that's going on.
>
> (APICS 4.10)

Given this shared awareness of how MRP2 use connects different activities, and groups, perhaps it isn't surprising that their examples of failure contain many stories of conflict between groups. Despite the absence of goal clashes or goal uncertainty in their explicit accounts of problems using the full MRP2 model, conflict between different uses of MRP2 play a central role in their failure stories.

I grouped the accounts of conflict between uses of MRP2 into three categories: direct clashes, indirect clashes, and incentive clashes. In the stories of direct clash, both conflicting groups are named openly. In the stories of indirect clash, one or more of the conflicting parties remains unnamed. The distinction between direct and indirect clash stories is useful because of one particular conflict that almost always goes unnamed: the conflict between planners and the manufacturing floor. In the stories of incentive clash, the MRP professionals interpreted group conflict as an incentive difference.

First, many examples of failures to use the full MRP2 model took the form of an open, direct clash between groups. At the center of these clashes were the group known as planners. Production planners are traditionally seen as the main users of MRP2 systems. Planners are responsible for the long to medium term scheduling of purchasing and manufacturing activities (scheduling months, weeks, or possibly days, rather than hours). Through the MRP2 system, for example, planners try to get design engineers to commit to a product structure known as the bill of materials. The bill of materials defines which parts and subassemblies are needed, and how many, to produce an end product.

> Within a company, you need one bill of materials. I've been in many companies that have, engineering has a bill of material system, and the planning and materials side, the manufacturing side has their own bill of materials system. And you're trying to compare two like databases, they're never going to match. Never going to happen.
>
> (APICS 4.2)

There is a recognition in their stories, however, that design engineers and planners have different perceived work needs. Planners sometimes create their own subassemblies in the bill of material for their own reporting convenience, or try to reduce the number of subassemblies and save on the administrative transactions associated with tracking subassemblies. Design engineers, however, argue that a bill of material structure which matches their engineering drawings best meets their information needs:

> I worked for this engineer who really was a genius. But all geniuses have their weaknesses. And I wanted to reduce the number of levels in the planning process and I once tried to say, let's go to the phantom, or the blow through. What are you going to call it? Well, I was going to call it planning bill six, or whatever. No, you can't do that because all part numbers have to have drawings, right? That was his rule. All part numbers have drawings, and the thing's too big to put on a drawing.
>
> (APICS 1.8)

The discussion of conflict in these stories is open and obvious:

> Because it's there only for the edification of the engineers, which we do things for from time to time. Because they like to make [subassemblies] up, and they have absolutely no real reason to exist in the world but they do

it...On the other hand, we sometimes do the opposite to make up for the fact that we don't like engineering and their drawings, and we sometimes create parts that don't exist in the engineering drawings. And so we call those planning bills. Hey!

(APICS 3.13)

The tensions around basic MRP2 data structures, such as the bill of materials, increase as more groups become involved. Through an MRP2 system, accountants can track product costs using the bill of materials as a standard. Outside parties can insist that certain subassemblies be tracked, through the bill of materials, for safety purposes. Both of these needs work against the planner who wants to reduce the number of subassemblies, and therefore reduce the number of internal transactions. The story below discusses phantom coding, a systems technique used by planners to group multiple subassemblies into a single subassembly, and reduce the number of transactions:

Remember we talked about phantom coding? This is another great way, then, of reducing the number of levels in the bill of materials, will also speed up your MRP processing time. [*Participant 3:* what is the disadvantage of doing that?] Well, allright, in accounting... [*Participant 3:* ...or if you sell subassemblies]. Ok, that's fine, if it is sold at the subassembly level that's fine, it's a spare. But, except for accounting, and the government, but you still have traceability at any level. Accounting doesn't like it. Accounting fights it. Because of the fact that these assemblies consume labor and overhead. They go in and out of inventory. So if you eliminate it, then what's the standard cost of this subassembly now? So there isn't any.

(APICS 1.8)

The lead times are another core MRP2 data structure that experienced MRP2 users identify as a source of difficulty. Lead times define, within the MRP2 system, the amount of time it takes to either purchase or manufacture a part. Making good predictions about lead times is difficult, and different groups benefit from having lead times on the "high side" or "low side," depending on their uses:

Purchasing will have a tendency to pad the lead times. And if I was a

> material planner, I would, you know, trying to go to an MRP system, or if I have an MRP system that I want to make run a little more efficiently, I would request through whatever means that purchasing evaluate all the lead times of their products...Purchasing and planning need to agree on what is an acceptable lead time. And that has to be a team decision. You know, consensus decision between them. Everybody has to agree. Purchasing's going to try and cover themselves by extending them, because as planners major problem, because the customer's going to call up, and it doesn't matter what lead time is in the system. If the customer wants it in four weeks, purchasing can have six weeks on the product.
>
> (APICS 4.6)

In the stories of direct clash, a group can be both condemned for pursuing their own objectives, and tolerated for having a legitimate need to be different. In this story, the sales group is condemned for causing an uneven workload when the orders are entered into the MRP2 system:

> But when you have an MRP system, what happens when there's an influx of paperwork in one area, and you've got a stack like this on one area? Let's say that sales, it's end of the month. Sales people have quotas. And all of a sudden, all these orders start coming through, right at the end of the month. It's a miracle how this happens...Salesman get their quotas, make their bucks. They go lay on the beach, do whatever they do after they hit their numbers. And the poor people in order entry have what? They've got a stack this high? How long does it take for them to get through that, and get it in the system, so they will go to MRP to know everything that's there?
>
> (APICS 4.15)

Yet the sales group is seen as having a right—a need—to be different, as we see in this account of how sales people tend to overinflate the sales forecasts that an MRP2 system depends on for accurate scheduling purposes:

> But sales people, they're daydreamers, you know. How much you're going to sell this year? $100 million, the guy says, you know, right? So then they say, OK, and that's the way he needs to be. He needs to be thinking big for your company. So he said, OK, now I want an accurate forecast. How much you're going to sell. A $100 million, he says, right? But, you know, in reality, when materials people get it, they slash it to shreds and everything. Well, in reality, that's what's going to come across from sales people.
>
> (APICS 4.7)

Another kind of direct clash story looks at the tension between the planners and the planned. The manufacturing workers are a group heavily affected by planning decisions, and, in practice, planners are not always able to get their way:

> Quite often you'll find that a foreman will say, just show me the entire month's schedule. I'll make what I want to make, and I'll give it to you when I want to give it to you. Not always the best way to operate, but sometimes the only way to operate, anyway. Again, called life.
> (APICS 6.6)

The stories of direct clashes include conflicts between the manufacturing firm and the outside world—suppliers and customers. For example, one professional describes how he formed a long-term relationship with a supplier by "promising" to buy a stable quantity for the next 65 weeks:

> [*Participant 8:* Doesn't that make it hard, I mean, I guess if your production's pretty stable for 65 weeks, then it's OK. But if your production in week 40 drops to 0, you're still going to be paying for excess] Nah, I lied to them. I didn't know what I was going to do in week 40. Didn't care. I only cared what I was really going to do in the next 4 to 6 weeks, realistically. And you've got enough lead time and flexibility, you can see some of that stuff coming. I mean, by the time week 40, you never worry about it. When you get down into week 10, and week 8, and week 6, then you start worrying about it. Realistically, you've got enough time to react in that time frame. So yeah, I lied. Oh well. I think it's called life.
> (APICS 6.3)

The key point to remember about the stories of direct clash is that MRP2 users consistently and openly attribute failures to use the full MRP2 model to conflicts between different activities, performed by different groups. The MRP2 professionals tell stories that focus on the diversity of goals and interests within manufacturing firms, a diversity that challenges the ideal of "one set of numbers" to run the business:

> What are the goals? Well, marketing wants the good stuff. They want a lot

> of inventory. Want to be able to turn on a dime, and respond to customer needs. They approve the master production schedule that will satisfy their demands. It's up to marketing to sell to the master production schedule. This is what they've asked manufacturing to build, manufacturing is building it to the schedule, they sell to it.
>
> (APICS 1.11)

In the accounts of failures to use the full MRP2 model I categorized as indirect clashes, the conflicts are just as open, but one or more of the conflicting groups are not explicitly identified. The findings for indirect clash stories are exactly the same, but I find it intriguing that one conflict dominates the indirect clashes: the tension between planners and the manufacturing floor.

Planners are supposed to use MRP2 as a model of what is actually happening, especially what is happening on the manufacturing floor. In their failure stories, however, they attribute MRP2 problems to the difficulty of making the model fit the factory reality. In bouts of cynicism, they call the standards on which the entire MRP2 system depends "meaningless":

> I've never paid a lot of attention to efficiency rate in practice anyway. Even when we were running as a job shop. Because, for one thing, it assumes that your standards are correct, which is usually an invalid assumption. [*Laughs from the audience*] It's usually a meaningless figure.
>
> (APICS 5.7)

Calling the time standards which form the basis of MRP2 calculations "meaningless" is a puzzling attitude that I could not explain using the rest of my data set. The meaning of these standards is not straightforward in the stories of failure to use parts of the full MRP2 model. The relationship between the MRP2 model and the factory floor has to be evaluated by the planner, using criteria that are not described:

> Now standard hours are a wonderful thing. Standard hours can literally

> mean anything you want. The naive approach is that it takes you 10 hours, 10 man- hours, to build a product, therefore there are 10 labor hours in it. Well, that's not true, and sometimes you get into the union aspects and all that, because sometimes your incentive wages screw all that stuff up. So you need to understand what your standard hours are, and how they relate to a capacity. What I'm saying is, if you have 10 people in a work center, and you've got a 40 hour week, that does not mean that you have 40 hours of available work.
>
> (APICS 6.5)

> I have found in my experience that defining work centers, and setting them up correctly, is not straightforward. Over the years, you know, I've changed my own work center definitions several times. You have to decide between having too many work centers, and increasing the amount of reporting and spreading out all the capacity data, and too few work centers, and having so many machines and so many people collapsed into one work center that your reports are meaningless, because very different kinds of jobs, kinds of parts go through that work center.
>
> (APICS 5.3)

Planners, according to these accounts, have to learn when the model will not work, or suffer the consequences:

> This stuff gets difficult. What is your maximum, average, and theoretical? Sometimes that gets into so many other areas of unknown that those are difficult to calculate. Your average is probably going to be what you're going to make. Your maximum hours capable, don't ever plan that. And your theoretical hours available, if you really want to lose your job quick, plan to that. Won't happen.
>
> (APICS 6.8)

> Another constraint in there is you never schedule to 100%, do you? Because you always have to allow for service, downtime, unexplained crises, and the owner's cousin coming in with that emergency order.
>
> (APICS 6.6)

How do the planners account for the discrepancies between the MRP2 model and the factory floor? The MRP2 users in the seminar attributed the difficulties to a gap between 'planning' and 'execution'. In contrast with Wight's vision, these MRP2 users claim that MRP2 was never meant to handle the "execution side", meaning the activities that take place on the shop floor. MRP2, in this account, is a 'planning' tool only, and those who tried to stretch MRP2 to include 'execution' did not do well:

> Planning. Planning. Does the MRP system do anything with actually implementing anything? It's planning. That's what a lot of people fail to realize. This is also why you get a lot of failures in MRP systems, is they say ah, we've got problems in our factory. Let's go out and get an MRP system. This was the craze back in the 60's and 70's was to rush out and get a system, OK? So they'd rush out and get a system, put it in, and they'd say, gee, our problems didn't go away.
>
> (APICS 3.1)

One of the major links between the planning of the schedule and realistic execution is the addition of capacity planning. Capacity planning uses the MRP2 model to test if a proposed schedule can be executed given a model of what each work station can produce, and the necessary routing of parts. Adding capacity planning to the MRP2 model is the major difference between MRP and Closed-loop MRP, or Class C and Class B MRP2. Integrated capacity planning, as an example of bringing the planning and execution sides of MRP2 together, was not treated kindly:

> You might say well, gee, why can't we just link everything together? Well, they tried that too, in the early days. Big campaigns about capacity system. They found out that didn't work either. So they've come to the conclusion that maybe we'd better plan capacity as a separate function. And that seems to work.
>
> (APICS 3.2)

Why the gap between 'planning' and 'execution', between the MRP2 model and the shop floor? Their interpretation of shop floor workers is partially one of shortsightedness and fear:

> One of the pitfalls of just in time, or a good MRP system, is the fact that we're now getting out of the order launching environment, and we're releasing work orders just when they're required. And it scares the hell out of the people on the shop floor. Why is that so? [*Participant 3:* they don't see a backlog]. That's right. They say the company's going out of

> business, because if they're not up here, up to the hips of their shop pants, they get nervous.
>
> (APICS 1.9)

While the MRP2 professionals belittle the shop floor workers, their stories of failures to use the full MRP2 model again recognize that the needs of manufacturing workers are different. Manufacturing workers have legitimate reasons for not working through the MRP2 system:

> I says well, why do you do it manually? He says, huh? What do you mean why? I says, well why don't you use the computer? He says, fffft. I says the reports, you know, the reports, he's got this stack of reports behind his desk about this high, and they pile up every day, you know, and he never touches them. I said, what are those for? And he says, not for me. He says, I don't use them. Why not? The data's two days old by the time I get it. We've got a fast moving manufacturing environment. What good is it to get a report that's 2 days old.
>
> (APICS 4.20)

When the MRP2 system does not meet manufacturing's perceived needs, they resort to using illegitimate manual systems—the infamous "black books":

> If you have someone who's only inputting data, and they aren't using the output, for whatever reason, it's not going to be accurate. Not going to be. Because they're still going to have their manual reports. They're still going to have their black books, you know. Oh, you'd be surprised. Oh man. You implement an MRP system, those black books and those manual systems, they still have them...When it gets down to it, when it's late at night and they open their drawer, they still got that old black book in there. You can call them whatever you want. They're around.
>
> (APICS 4.21)

In the clash between planning and manufacturing, it is not only the shop floor workers who are blamed for difficulties. Manufacturing management is also a contributor to problems using parts of the full MRP2 model, as in this story where a manager manipulated the order rules in MRP2 to improve their inventory status:

> But we've solved our problems. I said, how'd you do that? Well, what we did is we turned off the forecast, and we just built to the open orders. Boy, inventory came right down. It was really great. We cut the excess inventory. But then we got into some other problems because we didn't have stuff, so we turned it back on again...This guy, you know, was the vice president of operations. He's supposedly running this company. And he's out there tweaking the order rules on the front end of the MRP in order to get the inventory to come out right, OK? Deadly. Doesn't really, he's not working with the system, he's playing with it.
>
> (APICS 3.5)

Like the stories of indirect clashes between uses of MRP2, the accounts of failures to use the full MRP2 model attributed to 'incentive' differences displayed two features: an overwhelming interest in the clashes between planners and manufacturing workers, and an ambivalence over whether the different needs of other groups are legitimate. The key difference with stories of 'incentive' clash is an ambivalence over whether the planners should be using the MRP2 model, a supposedly 'accurate' picture of factory reality, as an 'incentive' for factory workers. The master production schedule at the heart of MRP2, for example, can be increased to give manufacturing the incentive to produce more:

> When we look at the problems of the master production schedule, we call it a wish list because they overstated. What would we like to make this? Or we overstate the master production schedule because we want to give manufacturing the incentive. We know we can't make it, but we'll put a little bit more in there, and just hope. Well, really, the thing to do is overbuild and leave a little slack in terms of capacity and material quantities. That's why you should be measuring performance as part of this monthly review process, measuring performance against the master production schedule.
>
> (APICS 1.6)

There are objections from the experienced MRP2 users, claiming that using the MRP2 model as an incentive corrupts its 'accuracy':

> You know, if it isn't achievable, why put it out there? If you can't do it, OK. You have management, says well I've got to have a goal for you to

> shoot for. Baloney. This is the master schedule. This isn't a motivation training class.
>
> (APICS 3.12)

MRP2 users interpret using MRP2 as an 'incentive' as a sometimes dangerous game. The planners themselves can fall prey to the temptation of manipulating the MRP2 model to meet their own incentives, such as reduced lead times, time standards in the factory, and reduced inventory levels:

> You know, the objective is to reduce setup times to next to nothing, but the data in your system, the data in your standard routers, has to reflect what the reality is today. If you still take 8 hours to set up a machine, the standard in the routing file needs to say it takes 8 hours. Can't cheat on it. Can't fool it.
>
> (APICS 5.3)

Despite the objections and the warnings in these accounts against using the MRP2 model as an 'incentive', the planners consider setting the proper 'incentives' for others through MRP2 an appropriate use of the system. In this example, the system was changed so that an overhead fee was charged for every work station on a part routing. The intent was to encourage the manufacturing manager to find a way to build parts with fewer intermediate manufacturing steps:

> We started absorbing a portion of the overhead based on number of operations, rather than on the traditional method of absorbing all that overhead based on labor hours. [*Participant 8:* So what that drives you to is the setup, or a massive reduction in operations wherever you can.] Exactly, exactly what happened. It set up the proper incentives to reduce the number of operations on the router. And it did save overhead.
>
> (APICS 5.8)

Strangely enough, these accounts saw unintended uses of the system as a legitimate means of creating 'incentives'. In this example, a planner assigns an arbitrary lead time to the Material Review Board, or MRB, which is where rejected items are taken for an undetermined length of time until the company decides whether to scrap or repair the item:

> [*Participant 3:* We have a work center on each routing called MRB.] [*Laughs from the audience*] Uh, yeah we didn't quite get to the point where we put it as a standard part of the routing. We certainly had an MRB work center that we were able to add it. [*Participant 1:* Yeah how'd you put a standard lead time on MRB?] [*Laughs from the audience*]...I put a month and a half lead time on that MRB operation. So that when people like sales would look in there, and try to follow up on a customer, it would give a calculation that they weren't going to get it until way out here. Because I was trying to set up the incentives to get it out of there, and get it moving.

Their ambivalence towards using the MRP2 model as an 'incentive' is nicely illustrated by this problem example, a classic tale of trying to run the factory at "110%". According to their accounts, a planner uses MRP2 as an 'incentive' at their own peril:

> The VP of operations came to me one day and he said [last name of speaker], for some reason or other, no matter what you schedule in the plant, they always run 90% of what you schedule. Always run 90%. He says, we're going to get around this. I want you to schedule the plant at 110%. Right on, boss. And I did it. Dumb. The next month, he says god damn it [last name of speaker]. Look at all that inventory out there! Queue, everybody's waiting in queue, we can't find orders, and we've got stuff stacked to the gills out on the shop floor. What the hell you got all that stuff out there on the shop floor and they can't build it for me? So I said something smart like, you told me to. Which is now why I'm in consulting.
>
> (APICS 6.8)

In this section, I discussed the first core category in my analysis of how experienced MRP2 users explain failures to use parts of the full MRP2 model. MRP2 users describe these failures as conflicts between different activities, and different groups, supported simultaneously by the MRP2 model. This explanation is very different from the reasons they explicitly give for failures to use the full MRP2 model. The stories of direct clashes in MRP2 use reveal a consistent awareness of conflict between groups, and between the manufacturing firm and the outside world. Other groups besides planners are chided for following different goals, but their different needs are seen as legitimate. The stories of indirect and incentive clash focus on the conflict between planners and manufacturing workers—the group most responsible for the MRP2 model, and the group most closely modeled. This clash is also criticized but considered legitimate. Stories of failures to use the full MRP2 model focusing on 'incentive' differences simultaneously condemn any use of the MRP2 model that detracts from its 'accuracy', but legitimately accept the MRP2 model as a place to create the right 'incentive' for others.

4.3 Orientations Towards MRP2 Use: Discipline/Flexibility, Commitment/Protection

In the previous section, we saw how problems with using parts of the full MRP2 model were attributed to the conflicts between different activities coordinated through MRP2. In this section, I show how the professionals describe how they reconcile the different uses of MRP2. In their accounts, MRP2 professionals see systems (for example, as "protection") in ways that lead to MRP2 breakdowns. I identified two kinds of tension in their explanations. One was a tension between the need for 'discipline' and the need for 'flexibility' in their relationship towards the system. Another was a tension between a desire for 'commitment' and 'protection' from others through MRP2 use.

The tension between 'discipline' and 'flexibility' in their accounts is summarized in Figure 4.3. 'Discipline' here is similar to the 'discipline' concept found in the earlier, traditional explanations. 'Discipline' is seen as an individual choice to behave as the formal system intends, and leads to an 'accurate' MRP2 model. The difference, however, is that 'discipline' in these accounts has to be balanced by a concern for 'flexibility'. 'Flexibility' means temporarily disregarding the formal system to cope with changing demands from the outside world. Maintaining a reasonable balance between 'discipline' and 'flexibility' is how these stories describe the reconciliation of individual and company interests with a changing outside world.

In their accounts of failures to use the full MRP2 model, a lack of individual 'discipline' leads to the use of the informal, non-computerized system. What is 'discipline'? As described in section 4.1, 'discipline' means being in control. A 'disciplined' person chooses to follow the formal procedures, which clearly benefit the company, rather than their own personal preferences. Discussions of 'discipline' portray human behavior in organizations as mechanistic:

> One very large company that I was doing an MRP system with, we hired three procedure writers, and their job was to follow each of the various heads of the departments around who were working on my team to set up the MRP, and write procedures. So that we would have a program for the human beings to follow just like we had computer programs for the computers to follow. Policies and procedures are the equivalent on the human side to the programs that you give the computer to execute over on the computer side.
>
> (APICS 3.4)

Individual 'discipline' depends on education and awareness, as in the traditional explanations of MRP2 failure. 'Discipline' also depends on personal dedication. A 'disciplined' person is a "fanatical" believer in the formal system, and doesn't get "comfortable" when the company is doing well:

> The key is to make the new system, and put all your effort and energy into that. Forget the other system. You can make anything work if you really put your mind to it.
>
> (APICS 4.5)

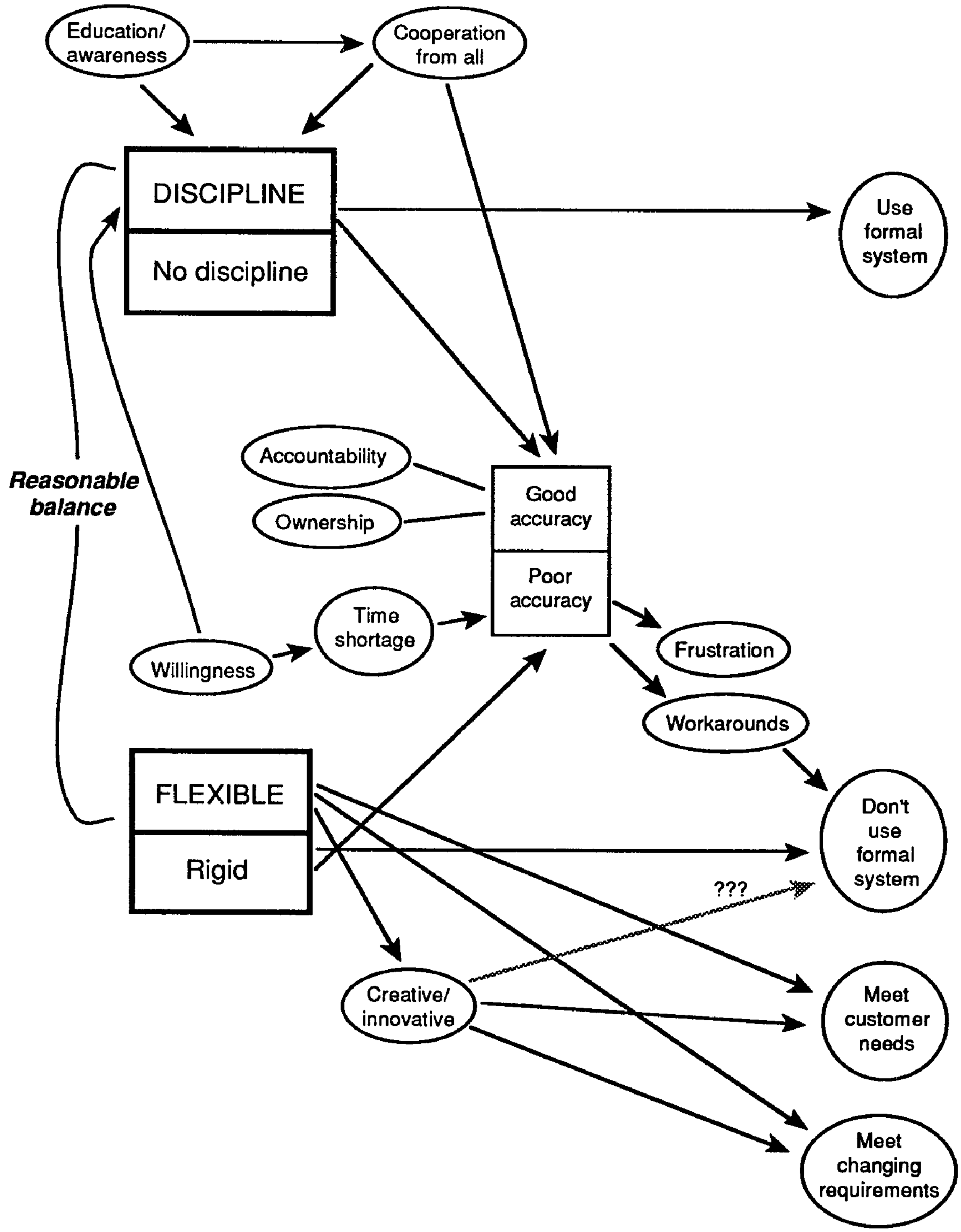

Figure 4.3: The Tension between 'Discipline' and 'Flexibility'

> People, they get real comfortable. If they're making a lot of money, and then you say hey, we need to install this new MRP system, and we need to do this. And they go, thing's are great, leave us alone. Well how did they get great?
>
> (APICS 4.11)

> Fanatical, you've got to be a believer. You've got to be a strong believer.
>
> (APICS 6.1)

Personal 'discipline' leads directly to good data 'accuracy', as in the traditional explanations. Other aspects of personal 'discipline', including a sense of 'accountability' for actions and a feeling of 'ownership', are key ingredients of good data 'accuracy'. 'Accountability' and 'ownership' in these accounts are described in individualistic terms:

> Cultivate ownership and accountability. We talked about that, didn't we, enough? About the culture that has to be there so that people feel that they have ownership for what they do, for the quality of what they do. Especially, for this discussion, anything relating to work that they do that impacts the accuracy of the data for MRP. OK? That everything that they do, that they write down. The workers who fill anything out, if you have that meeting and tell them how important it is that they don't transpose the digits. And please double check their job cards.
>
> (APICS 4.17)

> For anything that they're doing with paperwork, or reporting that involves an MRP system, they have to take ownership for the quality of what they're inputting, or what they're turning in. OK? If they just fill out a job card, buzzer just went off and head out the door, you know, run out to the parking lot, you know, they may have written down the wrong job number, the wrong quantity, the wrong operation, OK?
>
> (APICS 4.14)

'Discipline' in using the formal MRP2 system, however, cannot account for the stories in which MRP2 users must legitimately bypass the formal system. Legitimate use of informal systems is called 'flexibility'. The need for 'flexibility' to satisfy outside clients balances the need for 'discipline':

> You mentioned customer, which is very important with any system or

> procedure that you're going to implement, is that if the system is going to in any way interfere with satisfying customer needs, something's wrong. You haven't defined it enough. You haven't refined it enough. It's not flexible enough. It cannot impact the ultimate the goal, which is satisfying the customer.
>
> (APICS 4.2)

'Flexibility' in using the MRP2 system is necessary because of changing demands from the outside world, within a short time frame:

> You were mentioning, all these changes, right? In a just in time environment, you're not going to have time to go through reams of paper, are you? You have to react.
>
> (APICS 1.9)

> Maintain a stable schedule. Well, stable as, as stable as the world is in scheduling. I know there are companies that go in and tell you that you need to have a frozen, you know, time period. A frozen block, or this system won't work. Forget that. That's not reality. Anybody talking that is not from the real world. You can't freeze it. You've got customer demands.
>
> (APICS 4.9)

In the discussions of 'flexibility', people are generally willing to work within the system. In these accounts, people want to have the 'discipline' that benefits the company. But changing outside demands, in a short period of time, lead people to 'work around' the system despite their good intentions:

> So, what runs the company? The systems and procedures? I mean, everybody thinks they've got, boy, I've got written policies on everything. But people go around them all the time, because they're not flexible enough, what good are they? So, systems and procedures don't necessarily take care of how a company should run. Because people are going to get the job done regardless of roadblocks...And the fact that when you set something up, and you define, it's all with good intent, but you may be creating some of those roadblocks, some of that congestion on the freeway. And people are going to get frustrated. When they get frustrated, they're going to go around it. And when they go around it, if you haven't planned for that, you're going to have some problems with data integrity. You're going to have bad data. They're going to sneak parts out. They're going to do this, they're going to do that, they're going to do without paperwork, without

> input, and then you're going to have lots of problems.
> (APICS 4.1)

A key point to remember in these stories of failures to use the full MRP2 model is that the people have a legitimate need to be 'flexible'. They do not want to thwart the system for their own selfish gain:

> You've got to get your job done. So, when you're in the freeway and you're hitting the bumper to bumper traffic, and you're taking the alternate routes, why take them? Because you're just trying to get somewhere on time. Within your company, your systems and procedures, don't you try and go around them? Do you do it because you want to? No! You do it because you have to get a job done within a certain time frame.
> (APICS 4.1)

Do these stories imply that it is sometimes appropriate for people not to use the formal MRP2 system? That would be a major departure from the Class A MRP2 usage ideal. Although their stories of "freeways" and "roadblocks" suggest that 'flexibility' does make the informal system legitimate, the 'flexibility' comes in using MRP2 slightly differently from the model's original intent. In this story, an MRP2 consultant advocates using a data structure in a way that is not sanctioned by the system, in the name of 'flexibility':

> Now maybe you can be flexible, and you should be. Don't stick to your guns. Instead say, have you got another suggestion? If it works with this, we'll be glad to work with it. But if not, I've got to go back to this. So, give them the creativity because you can use different data fields in a lot of different areas of the computer to do things that, to be flexible, let's just put it that way. And so give the implemented the creativity. Open up, let them be a little creative on how to fit your need, whether the system is exactly defined for that or not.
> (APICS 4.19)

Understandably, experienced MRP2 users have a difficult time reconciling the need for 'disciplined' systems use with the need for 'flexibility' when outside demands change. 'Discipline' and 'flexibility' call for mutually exclusive actions—using the MRP2 system as intended by the full MRP2 ideal, or not. The best means they have of describing this tension is to call for a reasonable balance between 'discipline' and 'flexibility':

> One of the keys to a successful implementation is discipline, and yet being flexible enough to change systems and procedures. So, there's really two sides of it. Discipline, when people say you've got to do it by the book and you have to do it, you know, you've got to also be flexible enough to be willing to change it.
>
> (APICS 4.2)

A reasonable balance between 'discipline' and 'flexibility' is difficult to define, and my data did not provide enough accounts to let me pursue it further. This orientation, which plays prominently in their stories of failure to use the full MRP2 model, is self-contradictory in the way that the MRP2 users themselves have defined it. The only way they can find to reconcile 'discipline' and 'flexibility' is to conjure up a vision of a completely formal yet instantly changeable system. The formal system should be followed at all times, but should be immediately and completely changed when it faces new demands. I pushed this point with one of the session leaders:

> A company that wants to continually improve its processes, and we talked at break, I was talking to someone, they mentioned that I'm talking more about flexibility than has been brought up in some of the previous sessions. I don't want to get away from the fact that disciplines are critical, but you also, the disciplines and the policies are really critical to making MRP work effectively. But if you don't have the flexibility within your organization to encourage people to creatively think of innovative ways to improve the processes so they don't have to go around them, and be flexible enough that you'll take those ideas and change the process when it will make an improvement, and actually make it easier to do a job, whatever it may be, you're going to have problems.
>
> (APICS 4.16)

This vision of an infinitely flexible formal system shouldn't be tenable, yet it is one that apparently guides MRP2 users as they reconcile the different uses of MRP2. This is where we can see the limitations of our data. The accounts given in a professional seminar, away from their work, can be incomplete. The question of what meanings they use in practice to resolve these dilemmas is still open.

Finding a balance between 'discipline' and 'flexibility' is one type of explanation experienced MRP2 users give for how they reconcile the different uses of MRP2 systems. Another basic explanation I found was a tension between the desire for 'commitment', and the desire for 'protection' from the illegitimate demands of others, through the same MRP2 system. This tension is summarized in Figure 4.4.

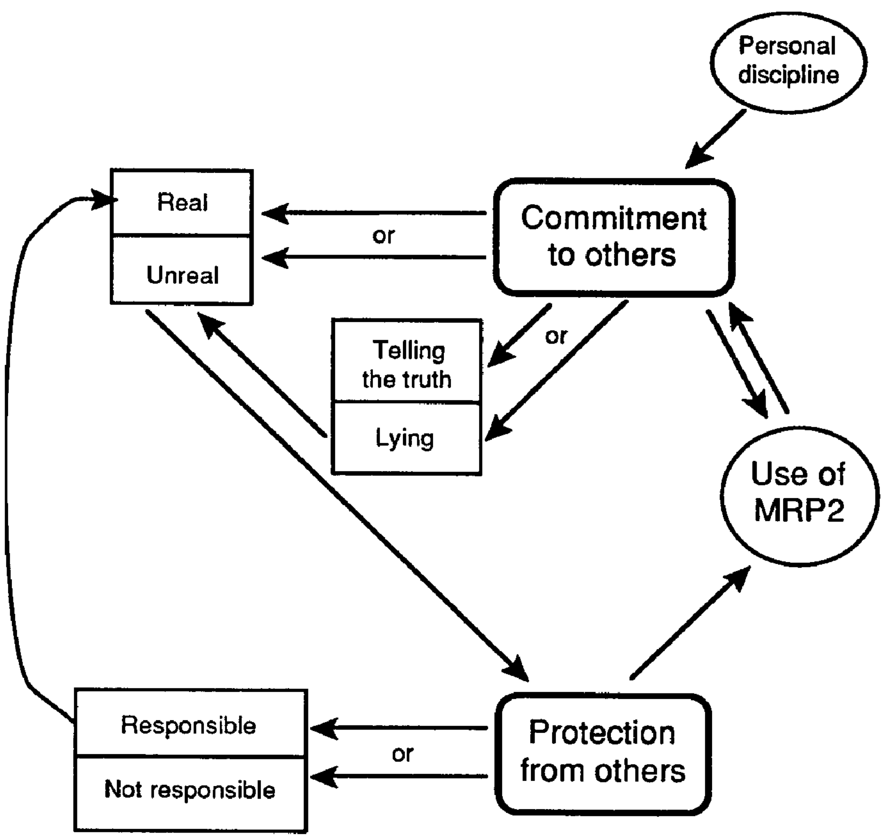

Figure 4.4: The Tension between 'Commitment' and 'Protection'

Key MRP2 data structures, such as the master production schedule, are routinely interpreted as a commitment between different groups:

> It's really the commitment of the master scheduler to the rest of the company. And you develop the master schedule, so marketing can sell to the master production schedule, purchasing's really going to buy to it, manufacturing is going to build from it. The master production schedule just drives all the other plans.
>
> (APICS 1.5)

For parts of the full MRP2 model to be used, these accounts make it clear that there needs to be a joint commitment to a wide range of policies, data collection strategies, and parameters. Otherwise, MRP2 cannot provide the "one set of numbers" needed to run the business:

> Agreement on what the requirements are and what your expectations are. A pricing philosophy compatible with MRP. You don't want them changing their pricing with every order, because it's a lot of extra work and it really skews all the data that you have in the system.
>
> (APICS 4.8)

Meeting the commitments is considered a key to MRP2 success:

> So, what's the most important thing? Meeting those commitments. If you deal with a company that really really rigorously uses their MRP, you had better get it there when you say you're going to, and with the quantity which you say. If you don't, you won't be their supplier any longer, OK? It is very important.
>
> (APICS 3.9)

When making commitments through the system, MRP2 users make a distinction between telling the truth and lying—not to each other, but to the MRP2 system itself. Are the commitments based on the 'truth', or a 'lie'?

> You can't let the open order dates get garbaged up. They've got to be real good dates. Because you've got a promise out there. It says I'm going to have this that date. MRP is going to count on it. It doesn't know you're lying to it. It believes you.
>
> (APICS 3.13)

> If you still take 8 hours to set up a machine, the standard in the routing file needs to say it takes 8 hours. Can't cheat on it. Can't fool it.
>
> (APICS 5.3)

According to these accounts, if you 'lie' to the system, you are only lying to yourself and to your customers. These 'lies' make the MRP2 model unusable. For example, the schedule for the current week in an MRP2 system is sometimes unachievable because work that wasn't completed last week was never rescheduled:

> We're in horse hockey, folks. According to this, we've got to do all these things in this period. We can only do this much. We're past due on all that stuff. We haven't bothered rescheduling. So we're lying to ourselves, and we're lying to our customers. That's standard American practice. Not smart practice, but standard American practice.
>
> (APICS 6.9)

The commitment through an MRP2 system, according to these stories, can be based on either a 'truth' or a 'lie' to the system. The resulting commitments, through the master production schedule or some other basic MRP2 data structure, can be either 'real' or 'unreal', realistic and attainable or not:

> The master scheduler should be updating and reviewing the master production schedule on a weekly basis. The senior management team should be reviewing and updating the master production schedule on at least a monthly basis. Must be realistic, that means attainable.
>
> (APICS 1.5)

While MRP2 use is seen as a way of securing commitments, MRP2 use is also interpreted in these accounts as a way of protecting planners from the illegitimate demands of others.

Experienced MRP2 users make a key distinction between activities they are responsible for, and activities they are not responsible for. Other groups are responsible for difficult problems, such as the accuracy of the forecast:

> So you're taking the bucks, and coming up with a set of numbers that say this matches it. Then you should turn it in to the management team that's responsible for forecasting and let them make the adjustments. Because you don't want to be holding the bag when people say, it's all Sally's fault, she didn't forecast right. See, that's what the president of the company gets paid for. To make these decisions.
>
> (APICS 1.4)

The tension between 'commitment' and 'protection' is a combination of creating and enforcing legitimate commitments through the MRP2 system, and ensuring that illegitimate commitments are not made through the MRP2 system. These kinds of accounts for MRP2 conflicts are interesting because they are dependent on perceptions about what are legitimate and illegitimate activities. For the planners, it is perfectly sensible to use the MRP2 system to make sure other groups make hard decisions that they are not legitimately responsible for:

> You could carry [extra inventory] here, right? You could carry it there, or at the raw material level, can't you? But who's going to make that decision? You're not going to make that decision, why? You're not going to make that decision. That's why we have chief executive officers who get these big stock options and big bonuses, for making these decisions. You know, accounting is going to get on your tail if you have too much inventory, aren't they? But where is our inventory? Well, it's made up of safety stock. Well, marketing says I want you to carry, you know, six weeks supply of inventory. That's crazy! You can't carry six weeks of everything, can you?
>
> (APICS 1.7)

> If you do have a constrained work center, and marketing comes up and says I'd rather have this part. You say wait a minute, all these components are scheduled to come in. I don't care which one you make, but you tell us which one we're not going to make. You want 50 of this part number? Then what other part number do you want 50 less of? That's their decision

> to make. All you're doing is selling capacity. Marketing sells products, you sell capacity. You provide so much capacity. Can't sell more capacity than you have.
>
> (APICS 1.7)

The MRP2 users see many kinds of MRP2 use problems—extra inventory, long lead times, and imprecise schedules—as 'protection' from outside uncertainty, or incompetence inside the company:

> We put buffer stocks in, and we put all this other garbage in there, and it inflates inventory. Because we're protecting ourselves from inaccuracies.
>
> (APICS 3.9)

Even when the planners use arbitrary lead times in the MRP2 model, this is considered legitimate if it provides legitimate 'protection':

> But somebody has got to make a new number up, a new estimate of when that's going to be ready. Otherwise, what'll happen is the MRP will continue to assume it's going to be there yesterday, and plan it that way, OK? You're far better off saying to yourself, well, I think the engineer's going to get it in six months, so therefore I'll put six months in. And then write a letter to the vice president so he doesn't miss it that says I just rescheduled this out six months because engineering won't give me a commitment. And that'll probably cause all kind of problems but it might in fact get the situation resolved. Might get you fired, too, but you know, you have to judge that on your own. You can't leave it.
>
> (APICS 3.10)

As added 'protection', planners appeal to the 'reality' of the MRP2 model. If the MRP2 model is based on 'real' commitments, and telling the 'truth', then the MRP2 system can be the impersonal bearer of bad news, rather than planner:

> I used to go up to the sales manager. Want to expedite it? Go up there, run upstairs and say, look, here are all the jobs that are going through this work center. I can give you any job you want. But if you want to take care of Boeing, then you call up Lockheed and tell them their order's not going to make it. You can have so many units a day. This is the backlog, this is the sequence. You can change the sequence, Marty, any way you want to. I

> don't care. But you're still going to get a 1000 units a day. No more, no less. They've got to understand that.
>
> (APICS 1.10)

The tension MRP2 users see between 'commitment' and 'protection' opens up a new type of conflict between groups: conflict over what demands a group can legitimately or illegitimately make on another. This tension has a complex relationship with the 'reality' of the MRP2 model. The 'reality' of the MRP2 model is used as a 'protection' device by planners, but planners also consider it legitimate to use arbitrary values in the MRP2 model for legitimate 'protection' purposes. Much of the 'reality' of the MRP2 model is made up of 'commitments' between groups, which depend on groups agreeing with each other rather than a set of impersonal facts.

This chapter reported the results of Study 1, an interpretive study of how MRP2 professionals explain failures to use parts of the full MRP2 model. The reasons experienced MRP2 users explicitly give for failures are traditional, individualistic problems. The actual examples they describe of failures to use the full MRP2 model, however, attribute MRP2 problems to the different, partially conflicting uses of MRP2. These examples repeatedly attribute problems to conflicts between groups within the organization, and between groups and the outside world. These conflicts are criticized by MRP2 professionals, but the groups are seen as having legitimately different information needs.

The experienced MRP2 users describe different ways of reconciling the different uses of MRP2, and these descriptions play a significant role in explaining failures to use the full MRP2 model. One tension they see, between maintaining 'discipline' and 'flexibility' in the use of MRP2, tries to reconcile the need for internal control with changing requirements from the outside world. Another tension they see, between 'commitment' and 'protection', tries to reconcile the legitimate and illegitimate demands of other groups through the MRP2 system.

Identifying two kinds of interpretations in their accounts of failures to use the full MRP2 model—differences between activities, and orientations towards use—formed the basis of a new positivist explanation tested in Study 2, and a new interpretivist explanation examined in Study 3.

Chapter 5
Study 2: How Differences Between Activities Affect MRP2 Use

The results from Study 1 suggested that failures to use parts of the full MRP2 model could be explained by differences between organizational activities: if MRP2 use coordinates activities with very different organizational demands, continued use would be less likely. In this chapter, I report the results from a case study which examined whether failures to use parts of the full MRP2 model at FLEXCO could be accounted for by differences between the organizational activities supported by MRP2. My answer is yes—the results suggest that trying to coordinate activities that are too different drives people away from using the shared, elaborate computer system.

The interview-based case study at FLEXCO, an award-winning, medium-sized electronics manufacturer in the western U.S., revealed 48 examples of failures to use the full MRP2 model of Class A use as defined by Wight (1984) and others. These failures to use the full MRP2 model were grouped into 9 major categories. (Methodological details for Study 2 are presented in Chapter 3.4).

In this study, I compared three different theoretical characterizations of important differences between organizational activities, taken from organizational sociology. The three organizational theories focused on whether differences in technical uncertainty, outside legitimacy demands, or beliefs about legitimate behavior held by groups inside the firm were the most crucial for explaining when parts of the full MRP2 model were not used at FLEXCO. The case study method is comparative (Ragin, 1994)—the presence or absence of theoretically defined factors were entered into a truth table, which is reduced to a single equation using the laws of boolean algebra (Chapter 3.4 contains a discussion of the comparative case study method). Using this comparative case study technique, I found that all three theories of organizational differences were needed to explain when parts of the full MRP2 model were not used at FLEXCO—no single kind of organizational difference lacked explanatory power.

5.1 Failures to Use MRP2 as Organizational Differences

As we saw in Chapter 2, the full MRP2 model—what Wight (1984) would characterize as Class A level use—calls for a computerized simulation of the manufacturing firm (Wight, 1984). The computerized simulation, according to this full MRP2 model, should be detailed enough to tell the manufacturing firm exactly what parts need to be made, and what parts need to be bought, at any particular time. The ideology of Class A MRP2 use argues that the simulation should provide "one set of numbers"—a single model for the entire manufacturing firm (Wight, 1984). Wight's definition of Class A MRP2 use has been used almost exclusively in the professional literature on manufacturing (e.g., Harrison, 1990) and in the information systems/manufacturing literature on MRP2 implementation (e.g., Anderson et al, 1982; Cooper and Zmud, 1990).

As we also saw in Chapter 2, most U.S. manufacturing companies do not use the entire MRP2 model advocated by Wight's Class A ideal. In this case study, I test whether failures to use parts of the full MRP2 model can be explained by differences in organizational activities supported simultaneously by MRP2. If the same organizational rules built into the MRP2 model are shared by activities that have to "do" different things—change more or less frequently, satisfy different rules and regulations from the outside world, , legitimacy demands from the outside world, or legitimacy demands from groups within the organization—then I predict that the MRP2 model will be less likely to be used. Organizational rules built into a computer system, facing conflicting demands, can only be stretched so far.

In my interview study at FLEXCO, I identified 48 examples of failures to use the full MRP2 model. How can failures to use the full MRP2 model be identified? Any examples of information use that have been listed as part of Class A MRP2 use, but are not used through the MRP2 system, are classified as failures to use the full MRP2 model. These MRP2 failures, as I call them, are not failures to use the information. The information may be used through paper-based systems, or through other (usually more local) computer systems. The full MRP2 model, as described by Wight (1984) and used by many others, is very clear in its demand that one system, and only one system, should be used to determine what parts should be made and bought. One system should be used by scheduling, inventory management, manufacturing operations, purchasing, design engineering, accounting, and quality to monitor the status of the factory, and make decisions about builds and purchases.

The full MRP2 model argues that, at a minimum, that the MRP2 system should be the only source of at least six kinds of information (Figure 5.1):

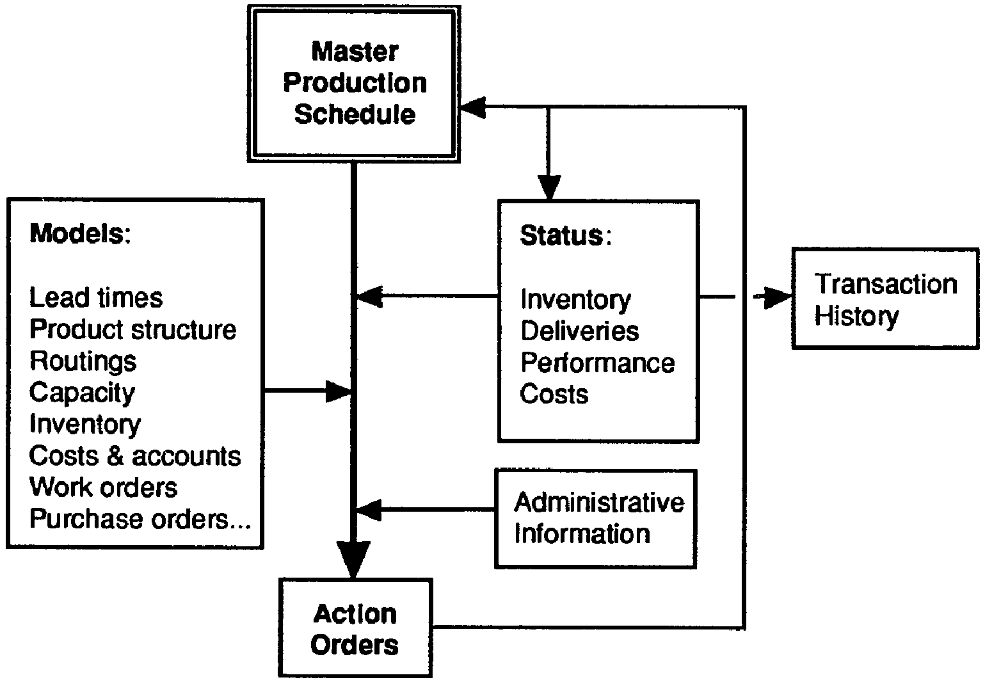

Figure 5.1: MRP2 Information Types

- The **master production schedule** is the heart of MRP2. The schedule is a computerized record of what final products need to be produced, by what date. According to the full model of Class A MRP2 use, all scheduling information should be contained within the MRP2 system.

- Various **models** of the manufacturing firm are used to convert the master production schedule into more precise action orders (e.g., "buy 100 of part C today", "start production of 25 Q subassemblies on line 12 in three days"). The important organizational model types include: the lead times, a model of how long it takes to make or build parts; the product structure (bill of materials) showing which parts and subassemblies are required to make a final product; the routings, a model of how parts are made through sequences of factory operations; the capacity model, which estimates how many parts an operation can produce at different quality levels; the inventory model, which distinguishes the types of available parts; accounting models, including product costs and accounts; work orders to monitor manufacturing operations; and purchase orders to monitor purchasing operations. According to the full model of Class A MRP2 use, these organizational models should all be included in the MRP2 system.

- **Status** information shows the current state of the factory, with respect to the organizational models. When are parts being delivered? How many of each part are in stock, and what status do they have? How many parts are manufacturing operations producing? What are the actual purchasing costs? Manufacturing costs?

- **Administrative information** is used to further specify action orders, but changes less frequently than status information. Administrative information includes: names and addresses of suppliers, customers, and employees; approved parts lists; credit and return policies of suppliers; and tax information. Administrative information can be used to turn a general action order ("buy 100 of part C today") into a precise purchase order ("buy 100 of fastener #304-4 from company XYZ at this address today, on 60 day credit").

- The **action orders** are generated by the MRP2 system from the master production schedule, using the information provided by the factory models, the status information, and the administrative information. The action orders tell the manufacturing firm when to start purchases, and when to start manufacturing operations, in order to achieve the master production schedule (or reveal that the current schedule is not achievable, given its model of the factory). The action orders can be used to update the status of the factory, or to update the master schedule. According to the full model of Class A

MRP2 use, decisions about making or buying parts should only be made using the MRP2 model.

- The **transaction history** keeps a record of old status information for comparison and long-term analysis.

I identified 48 specific examples of information use at FLEXCO that should have taken place through MRP2, according to the full MRP2 model, but did not. The 48 examples were grouped into 9 major categories. The 9 major categories are shown in Table 5.1, along with the two predominant organizational activities that are coordinated through this information. Again, an entry in this table signifies that a particular use of information, which links two organizational activities together[1], is not taking place through the MRP2 system.

In the next three sections, I compare how well three different theoretical characterization of the differences between organizational activities explain these examples failures to use the full MRP2 model. Each organizational theory concentrates on one kind of possible difference between organizational activities. Structural Contingency Theory focuses on differences in technical uncertainty (differences in complexity and amount of change) between organizational activities, and whether different degrees of change and complexity make sharing the same part of the MRP2 model difficult. Institutional Theory focuses on the different outside legitimacy demands that organizational activities are subject to, such as outside safety requirements, government regulations, and professional codes of practice. Social Rule System Theory focuses on disagreements between groups in beliefs about

[1]In practice, any use of shared information may tie together more than two organizational activities. In order to simplify the analysis, I only focus on the two dominant activities, as described by the respondents themselves.

legitimate behavior, or the "right way" to use the MRP2 system. For each example of an MRP2 failure at FLEXCO, the groups which are primarily responsible for the organizational activities linked together (for examples, buyer/planners for scheduling, quality engineers for quality assurance, etc.) may disagree about legitimate uses of the information. Using Ragin's (1994) comparative method, I code each major category of failure to use the full MRP2 model at FLEXCO as having a significant difference, or no significant difference, with respect to the three organizational theories.

Table 5.1: Major Categories of Failures to Use the Full MRP2 Model at FLEXCO

Information not used via MRP2	Activities linked
Inventory Details *Extra information used to track inventory on the factory floor.*	Scheduling-Inventory
Daily Deliveries *Information on incoming parts and materials that are delivered on a daily or hourly basis.*	Scheduling-Inventory
Outside Quality Reports *Reports on assembly line quality that are intended for outside suppliers and customers.*	Internal Quality-External Quality
Customs Information *Information on costs and country of origin needed to comply with U.S. Customs free trade zone regulations.*	Foreign Inventory-Other Inventory
Lot Tracing *Information for tracking which suppliers and manufacturing operations were used to make a product.*	Inventory Across Product Lines
Special Bills of Material *Specially modified information on which parts, and in what quantity, are used to make a product.*	Engineering-Scheduling
Detailed Schedule *Production scheduling details and history not maintained on the MRP2 system.*	Scheduling-Manufacturing
Shortage List *Information on which parts will soon face shortages at the currently scheduled rates of production.*	Scheduling-Manufacturing
Line Performance *Detailed information on how well assembly lines, assembly areas, and machines are making products.*	Scheduling-Manufacturing

5.2 Differences in Technical Uncertainty: Structural Contingency Theory

According to Structural Contingency Theory, technical uncertainty is a key characteristic that differentiates organizational activities. Differences in technical uncertainty are characterized as differences in complexity—the number of items or factors that have to be considered at any one time—and as differences in the frequency of task changes (usually operationalized as changes in the formal attributes of the task, such as changes to a schedule). If one assembly line make the same product for a whole month, while another assembly line has to switch between ten different products, the two manufacturing tasks can be considered as having different levels of technical uncertainty. If buyers have to cope with 30 or 40 scheduling changes per month from their suppliers, while shop floor workers only see three or four schedule changes per month, then the two tasks can be considered as having different levels of technical uncertainty (along that dimension of their tasks, assuming the changes are comparable in magnitude).

The difficulty of coordinating activities with different levels of technical uncertainty through MRP2 is captured in Conjecture 1: *the use of MRP2 information to jointly coordinate separate activities is less likely between activities with different levels of technical uncertainty*. For each category of failures to use the full MRP2 model, I coded the activities as having different levels of technical uncertainty if: a) all the groups involved consistently perceived a significant difference in complexity, or frequency of changes; and b) there was an obvious difference in complexity or change measures from the MRP2 systems data. (See Section 3.4 for details).

In this section, I will discuss one class of failures to use the full MRP2 model at FLEXCO. This class of information uses (inventory details, and daily delivery information—the first two rows of Table 5.1) was coded as linking organizational activities with different levels of technical uncertainty. These failures to use the full MRP2 model were not coded as linking organizational activities subject to different outside legitimacy demands, or that are dominated by groups with different beliefs about MRP2 use. In short, these examples faced the challenges of technical uncertainty differences, but not outside institutional differences or social rule system differences.

At FLEXCO, information was used to track inventory on the factory floor that was not maintained in the MRP2 system. The warehouse and the factory floor used labels, stickers, whiteboards, and separately printed barcodes to track inventory in more detail, and with more immediate visibility, than the MRP2 system. The 14 specific failures to use the full MRP2 model are shown in Figure 5.2

Inventory Details
Extra information used to track inventory on the factory floor.

Kit Control Numbers
Inventory Adjustment Notes
Production Line Inventory Reports
Key Cap Bag Stickers
Detrash Labels and Reports
Warehouse Part Labels
Return to Sender Labels
Part Bin Labels
Barcodes
Perpetual WIP Tracking by Dollar Value
WIP Tracking on the Factory Floor
Cycle Counting Worksheets
Warehouse Performance Statistics
ISO 9001 Labels

Figure 5.2: Inventory Details

While the full MRP2 model is technically able to provide a complete inventory model that tracks parts at the same level of detail as labels and tags, FLEXCO uses the MRP2 model as a less fine-grained tracking device. In some areas, such as the incoming parts warehouse, the MRP2 model matches the information workers see on the floor. For the

Work In Process areas (i.e., for inventory that is on the assembly line in the process of being used), MRP2 does not keep track of inventory information at the same level of detail. A year before my study, FLEXCO tried to track WIP inventory by implementing a new MRP2 module called "Repetitive Manufacturing". Six months later, FLEXCO abandoned WIP tracking through MRP2. Despite the dreams of buyer/planners, who hoped that WIP tracking through MRP2 would give them the inventory information they needed to do more accurate schedule adjustments, WIP tracking through MRP2 required too much computer transaction work for too little gain in inventory accuracy.

The two primary activities coordinated through inventory tracking are scheduling, and the management of inventory. I coded scheduling and inventory as being characterized by different levels of technical uncertainty with respect to inventory details. My informants from inventory, buying/planning, and material coordination (who act as a liaison between buyer/planners and the factory floor) all agreed that the planners and the inventory workers face different timeliness demands, and need to know different levels of detail. This was further supported by observations from informants in accounting and information systems. The systems data also suggested that scheduling and inventory are characterized by different levels of technical uncertainty. The accuracy of inventory records, even between six month physical inventories, hovered between 99.1 and 99.8 percent (by dollar value). Inventory adjustments on the system averaged 31 a quarter during the two quarters before my study. The production schedule is nowhere near as accurate, according to the systems data. Only 90 days into the future, the schedule may only have a 35 to 40 percent accuracy. Schedulers faced an average of 403 purchase order adjustments a quarter.

The two activities, scheduling and inventory management, were coded as not being subject to different outside legitimacy demands. No mention was made in any of the buyer/planner or inventory worker interviews of external legitimacy demands that had to be satisfied through this kind of detailed inventory tracking. The two activities were coded as not linking groups with different beliefs about legitimate information use. Despite the failure of an expensive WIP tracking project through MRP2, all the buyer/planners interviewed accepted the reasons for failure as a legitimate difference in the workings needs of the warehouse and factory floor, and the inventory workers did not challenge their legitimate desire to know this information.

A second category of failures to use the full MRP2 model at FLEXCO, daily delivery information, showed the same pattern of organizational differences: differences in technical uncertainty, but no difference in outside legitimacy demands, or in internal beliefs about legitimate MRP2 use. This is reasonable, because daily delivery information links the same two activities as inventory details: scheduling and inventory management. For high-volume parts purchased on a daily basis from the same supplier, the MRP2 model only contained information about a "blanket purchase order" issued on a monthly or yearly basis. The specific quantity of a part needed that day would be faxed to the supplier, and the incoming warehouse would credit shipments to a specific purchase order when the parts were received. The three specific examples of failures to use the full MRP2 model at FLEXCO are shown in Figure 5.3.

Daily Deliveries
Information on incoming parts and materials that are delivered on a daily or hourly basis.

Daily Delivery Purchasing Requests
Daily Delivery Performance Reports
Daily Delivery Warehouse Transactions

Figure 5.3: Daily Deliveries

Again, while the MRP2 system can technically generate a purchasing and receiving transaction for every daily delivery part, FLEXCO only tracks weekly or monthly totals in their system. While the people directly responsible assembly line inventory levels have to worry about hourly and daily totals, the buyer/planners felt that the coarser-grained "blanket purchase orders" better met their needs.

I coded scheduling and inventory as being characterized by different levels of technical uncertainty with respect to daily deliveries, though in the opposite direction from inventory details information. Daily delivery amounts change dramatically from one day to the next. For scheduling purposes, however, I was only able to find one purchase order adjustment in the MRP2 system for these longer-term "blanket purchase orders" over a 6 month period (and it was a clerical error). The frequency of important changes caused by daily delivery information in the production schedule for the buyer/planners is much lower.

I coded scheduling and inventory management as not being subject to different legitimacy demands from the outside environment. Neither the buyer/planners nor the inventory workers interviewed mentioned any important outside legitimacy demands. I coded the activities as not linking groups with different beliefs about legitimate MRP2 use, because I could not find a single legitimacy complaint about daily delivery information in the buyer/planner and inventory worker interviews.

5.3 Differences in Outside Legitimacy Demands: Institutional Theory

According to Institutional Theory, an important difference between organizational activities lies in the kinds of legitimacy demands they are subjected to by powerful entities outside of the organization. A legitimacy demand comes from an outside entity enforcing regulations, laws, or professional codes of practice that dictate how an organizational activity must be performed. Activities are subjected to either either weak or strong legitimacy demands from safety regulations, government laws, and professional codes. An outside entity, such as an ISO 9000 auditing firm, may place severe demands on how engineering change control must be done, but almost no demands on engineering design activity itself.

The difficulty of coordinating activities with different outside legitimacy demands through MRP2 is captured in Conjecture 2: *the use of MRP2 information to jointly coordinate separate activities is less likely between activities with different degrees of collective external organization (institutionalization).* For each category of a failure to use the full MRP2 model at FLEXCO, I coded the activities as having different outside legitimacy demands if: a) all the groups involved consistently perceived a significant difference in outside legitimacy demands; and b) there was a difference mentioned in the company newsletter archives.

Three categories of failures to use the full MRP2 model at FLEXCO were coded as having different outside legitimacy demands: quality reports intended for outside suppliers and customers, information required by US Customs free trade zone regulations, and information tracing the supplier and manufacturing history of products. All three of these categories were coded as only being characterized by outside legitimacy differences. They were not coded as coordinating activities with differences in technical uncertainty, or as linking activities dominant by groups with different beliefs about the legitimate use of MRP2.

Our first example of an MRP2 use failure associated with reconciling different outside legitimacy demands is product quality information. Although monitoring product quality was never considered a strong point of the MRP2 model, the full MRP2 model should be able to track quality through its status information: parts that are scrapped, rejected, or returned to the vendor provide an indicator of quality. Modern quality practice demands more than defect trends, however; it insists on establishing upper and lower control limits on the variability of processes, and on keeping information that traces quality problems back to their ultimate source. Figure 5.4 lists two examples of failures to use the full MRP2 model at FLEXCO, in the sense that they include reject and scrap information that should be provided by a Class A MRP2 system.

Outside Quality Reports *Reports on assembly line quality that are intended for outside suppliers and customers.*

Long Term Quality Trend Reports
Monthly Quality Reports

Figure 5.4: Outside Quality Reports

The two quality reports listed above, tracking longer term trends in product quality, were created at the request of outside customers. The outside customers wanted proof that FLEXCO had a strong quality system in place. In other words, outside customers demanded these reports as proof that FLEXCO followed accepted quality procedures. Were these reports used within FLEXCO, by the quality engineers, design engineers, and manufacturing managers who tracked product quality within FLEXCO? They were not, my informants consistently told me. The specific data collection and reporting system in place to produce these reports was only used for outside customers.

The full MRP2 model suggests that one set of quality data should be used for all activities. However, FLEXCO had created a parallel system to generate quality data for outside reports. I coded the activities for supplying internal quality information and external quality information as being subject to different outside legitimacy demands. Both the quality engineer responsible for outside quality reporting, and the quality engineers and buyer/planners who used internal quality information, claimed that this parallel quality reporting system only existed because of strong demands from outside customers. The company newspaper archives told of repeated customer quality audits at FLEXCO, and how important these audits were for the company.

I coded internal and external quality reporting as being characterized by no difference in technical uncertainty. The products that were subject to external quality reporting covered the full range of complexity and frequency of change: from one line of simple, stable keyboards, to a complex auto clockspring. Products that were very similar in their technical demands, such as different keyboard models, had very different external quality reporting requirements. I coded internal and external quality reporting as not linking activities dominated by groups with different beliefs about legitimate MRP2 use. There was one legitimacy complaint from a quality engineer, arguing that FLEXCO should use the outside quality information internally. However, none of the informants involved in internal and external quality complained about the illegitimacy of obtaining the external quality information, or giving the external quality information to the customers.

Customs information is a second category of a failure to use the full MRP2 model at FLEXCO where, like outside quality reports, differences in outside legitimacy demands are relatively more important than differences in technical uncertainty. The US Treasury department allows companies to declare themselves as "free trade zones". In a free trade zone, no import duties are paid on imported parts and subassemblies that are used solely for exported products. As a free trade zone, FLEXCO must keep a record of the costs and country of origin of duty-free parts for tax purposes.

The two specific failures to use the full MRP2 model at FLEXCO are listed in Figure 5.5.

According to the full MRP2 model, all information that affects the availability or status of inventory must be kept by the MRP2 system. According to U.S. tax law, imported free trade zone parts must not be used for products sold in the U.S. Yet FLEXCO kept free trade zone information on a separate personal computer in the warehouse. The warehouse workers and accountants saw little risk of duty-free parts being used on domestic products, but they did see a big risk in changing the centralized MRP2 system. Even six months into the project, FLEXCO employees responsible for foreign parts were unsure exactly what needed to be tracked and reported to U.S. Customs. Changes to the centralized MRP2 system were complicated and expensive.

Customs Information *Information on costs and country of origin needed to comply with U.S. Customs free trade zone regulations.*

Free Trade Zone Parts Codes
Free Trade Zone Bills of Material

Figure 5.5: Customs Information

The inventory information links two activities: managing foreign inventory, and managing all other inventory. Managing foreign inventory and all other inventory were coded as being subject to different outside legitimacy demands. The inventory workers and supervisors interviewed all claimed that foreign inventory demanded extra information, and that information was required by U.S. Customs. The newsletter archives contained one discussion of the "free trade zone" and how important it was for FLEXCO.

Foreign inventory and all other inventory were coded as not being characterized by different levels of technical uncertainty. Inventory workers and supervisors gave no examples of how foreign inventory and other inventory differed in complexity, or in frequency of changes. Most free trade zone parts tended to be high-complexity automotive parts, but they also included mundane switches, plates, and plastic moldings. Foreign inventory and all other inventory were coded as not linking activities dominated by groups with different beliefs about legitimate MRP2 use. There are no claims in the interview data that any group was using the foreign inventory information illegitimately.

Lot tracing information is the final example of outside institutional differences at FLEXCO. Lot tracing information is used to track the history of a manufactured product—which supplier did parts come from, and which machines and personnel produced this product? For safety critical parts, outside entities demand the extra accountability of lot tracing. If a part fails, investigators can use lot tracing information to pinpoint which supplier or manufacturing process is to blame. Figure 5.6 lists the specific failures to use the full MRP2 model at FLEXCO categorized as lot tracing information.

Lot Tracing *Information for tracking which suppliers and manufacturing operations were used to make a product.*

Auto Parts Lot Numbering
Trace Sheet for Voided Lots
Shop Traveler (Final Testing to Shipping)

Figure 5.6: Lot Tracing

The most frequent use of lot tracing information at FLEXCO was for a single assembly line. This assembly line made a safety-critical part: an air bag activator switch for automobiles. This one line used a separate local area network to provide lot tracing information unique to that product. Though the full MRP2 model calls for full traceability through MRP2 information, FLEXCO used a system for lot tracing that was completely separate from their MRP2 system. According to the full MRP2 model, there is no reason why extra inventory information should be kept outside of MRP2.

I coded the two activities that are coordinated by lot tracing information—inventory management for the air bag line, and all other inventory management—as being subject different outside legitimacy demands. All of my informants in design engineering, manufacturing, and material coordination involved in lot tracing agree that the lot traced parts are subject to very severe safety demands that other parts are not. The newsletter archives report that the separate local area network for the assembly line producing safety-critical parts was acquired primarily for liability protection.

I coded the two different kinds of inventory management as not being characterized by different levels of technical uncertainty. There was evidence, particularly in the systems data, that inventory management for automobile parts is less complex, and more stable, than for other parts. The automobile division, at the time of my study, had to manage 1085 parts, while the computer products division managed 6365 parts. One manufacturing informant claimed that automobile division inventory was simpler, and more stable, than other inventory. Other informants, however, disagreed. The design engineers, material coordinator, and buyer/planners interviewed claimed there was little or no difference in complexity or stability. I coded lot tracing as not coordinating activities dominated by groups with different beliefs about legitimate MRP2 use, because there were no complaints in the data about illegitimate uses of lot tracing information.

5.4 Differences in Beliefs About Legitimate Behavior: Social Rule System Theory

For Social Rule System Theory, activities can be characterized by the social rule system that actors use to guide their behavior in a particular, proscribed action domain. Social rules systems can be thought of as schemes of legitimate behavior—defining who can legitimately do what, where, where, and how, for what reason (Burns and Flam, 1987). One major source of dynamic tension in organizations, according to Social Rule System Theory, is the contradictions that arise when different, mutually exclusive social rule systems are applied to the same activity. For this study, I am particularly interested in examples of groups having different schemes of legitimate behavior for how to use part of an MRP2 system. For example, manufacturing management may increase the volumes in the master production schedule as an incentive for floor workers to do more, while the schedulers may argue that the schedule should never exceed the formally defined capacity of the factory, no matter how motivational they might be.

The difficulty of linking activities dominated by groups with different beliefs about legitimate MRP2 use behavior is captured in Conjecture 2: *the use of MRP2 information to jointly coordinate separate activities is less likely between activities governed by conflicting social rule systems.* For each category of failures to use the full MRP2 model at FLEXCO, I coded the activities as being governed by conflicting social rule systems if all the groups involved consistently complained about illegitimate uses of MRP2 information by the other groups.

One category of failures to use the full MRP2 model at FLEXCO, customized product structure information, was coded as only being characterized by a difference in social rule systems. Customized product structure information was coded as not being characterized by either different levels of technical uncertainty, or as being subject to different outside legitimacy demands. However, three other categories of failures to use the full MRP2 model at FLEXCO was coded as linking different social rule systems, and activities that are described by different levels of technical uncertainty: production scheduling details not kept on the MRP2 system, information on upcoming parts shortages, and detailed information on assembly line performance.

Information about product structure, known as the bill of materials, is a key data structure in the MRP2 model. The bill of materials links design engineering and scheduling by allowing a schedule of finished products to be broken down into a schedule for specific parts. The bill of materials, because it tells the MRP2 system which parts are needed, affects other activities that must know which parts are being used: cost accounting, quality checking, and manufacturing. At FLEXCO, groups sometimes added their own extra information to the bill of materials outside of the shared MRP2 model. These specific failures to use the full MRP2 model at FLEXCO are listed in Figure 5.7.

Special Bills of Material *Specially modified information on which parts, and in what quantity, are used to make a product.*

PCB Parts List and Restock Diagram
Packaging Information on Bills of Material
Special Accounting Bills
Regulatory Safety Check of Bills
Samples Parts Lists and Diagrams

Figure 5.7: Special Bills of Material

The dilemma of the bill of materials is that design engineering has the obligation to keep product structure information up to date, yet has many temptations not to. First, as a group with professional expertise, design engineers usually have discretion over whether and when they perform "bureaucratic" activities (see Chapter 4) such as updating the MRP2 model. Second, because product changes have such wide-ranging effects within the MRP2 model, they must be controlled. This control impinges on the "design freedom" of engineers, particularly in the early stages of the design. All MRP2 models now have a technical mechanism (separate types of bills) for coping with this dilemma, but the fundamental problem remains. When the design engineers do not keep the bills of material up to date, other groups keep their own extra information. Quality engineers, for example, kept their own information about safety certification. Manufacturing groups kept their own lists of which parts were needed.

The two major activities coordinated by bill of materials information are design engineering and scheduling. I coded these activities as being dominated by groups with different beliefs about legitimate MRP2 information use. My engineering informant regularly complained that updating bills was unjustifiably difficult, and that many details should have been work for "secretaries", not engineers. On the other side, the material coordinators and the manufacturing supervisors involved in scheduling complained that the behavior of design engineers was illegitimate (though accepted as inevitable). Other interviews in accounting and quality engineering were consistent with this coding.

I coded design engineering and scheduling as not being subject to different outside legitimacy, with regards to product structure information. The difficulty of maintaining bills of material was never associated with outside demands in the interview data. I also coded design engineering and scheduling as not being characterized by different levels of technical uncertainty, in terms of product structure information. None of the informants, from any group, could see a difference in complexity or stability between the bills that were usefully shared and the bills that were not. This is surprising, since a design that changes rapidly would appear to face more problems. Yet, the bills were seen as following a common pattern across all types of products. Perhaps the fact that bills of material combine slow-changing and fast-changing parts explains why none of the bills were seen as having different technical demands for scheduling.

In the three remaining examples of failures to use the full MRP2 model at FLEXCO, I found evidence of both important differences in technical uncertainty, and differences in beliefs about legitimate MRP2 use by the groups which had to share MRP2 information. All three examples revolve around the crucial link between scheduling and manufacturing. In general, scheduling and manufacturing are characterized by different levels of technical uncertainty, at least for activities closely related to the MRP2 model. Schedulers must cope with changes in the internal and external environment, while manufacturing is buffered from many of the external changes. All three examples report differences in beliefs about legitimate behavior between the schedulers and the "schedulees": who should be able to change the schedule, and who should know performance details?

In all three of the remaining examples, I coded scheduling and manufacturing as not being subject to different outside legitimacy demands. None of the informants reported that scheduling and manufacturing faced different institutional demands around the detailed schedule, the shortage list, or line performance information.

A central tenet of the full MRP2 model is that all production scheduling information should be obtained through MRP2. At FLEXCO, however, there were examples of scheduling information that were not used through the MRP2 system. Previous schedule history and 120-day schedule summaries were not kept on the MRP2 system. A separate, short-term scheduling system was used for 5 day scheduling profiles on stable products. And many of the scheduling details were worked out in cross-functional team meetings, using schedules built on spreadsheet programs. The specific failures to use the full MRP2 model at FLEXCO are listed in Figure 5.8.

I coded scheduling and manufacturing as being characterized by different levels of technical uncertainty. Both buyer/planners and manufacturing supervisors reported in their interviews that schedulers had to cope with more uncertainty: the sales forecasts were inaccurate, some orders had to be placed "on faith" (i.e., before they were actually ordered by the customer) to meet deadlines, and customers made dramatic changes in their orders. Manufacturing supervisors claimed they did not "have the time" to wait for schedule changes to come through the MRP2 system. The systems data showed that schedulers were not using the MRP2 master production schedule as an exact schedule. Instead, they were "frontloading" the schedule to cope with rapid change: entering monthly or weekly estimates, rather than scheduling in daily increments.

Detailed Schedule *Production scheduling details and history not maintained on the MRP2 system.*

Daily Line Lead Sheet
Previous Quarter Schedule History
120 Day Schedule Summary
Forecast vs. Shipping Reports
Electronic Orders
5 Day Scheduling Profile

Figure 5.8: Detailed Schedule

I also coded the detailed scheduling information as coordinating activities dominated by groups with different beliefs about legitimate MRP2 use. Manufacturing management, inventory management, and even the buyer/planners themselves complained about illegitimate uses of the scheduling information. Buyer/planners were accused of (and private acknowledged) working around the scheduling system when it fit their preferences. A materials manager argued that buyer/planners had a legitimate need to bypass the overhead involved in formal schedule changes under certain circumstances. Material coordinators claimed that production supervisors were manipulating scheduling information—in particular, the minimum number of workers they needed—to fit their own agendas. The production supervisors were visibly reluctant to complain about other groups, but even they claimed they couldn't always follow the formal scheduling procedures under pressure.

The shortage list, another example of a category of MRP2 use failure at FLEXCO, displayed a similar pattern. According to the full MRP2 model, the MRP2 schedule should be used to determine which parts need to be ordered. FLEXCO, however, used a customized system (running on the same VAX computer as the MRP2 system) to generate shortage lists and pick lists for certain products. Shortage lists describe which parts will soon run short at the current rate of consumption. Pick lists describe which parts should be taken from the warehouse to meet current production needs. The customized system created by FLEXCO employees used bill of materials information from the MRP2 model, but entered the scheduled demand and current inventories manually. The customized shortage list system was described by one informant as a "mini-MRP on the side". The specific failures to use the full MRP2 model at FLEXCO categorized as shortage list information are listed in Figure 5.9.

Shortage List
Information on which parts will soon face shortages at the currently scheduled rates of consumption.

Where Used Report
Shortage List with Drop Dead Dates
Shop Floor Pick List

Figure 5.9: Shortage List

Scheduling and manufacturing were coded as being characterized by different levels of technical uncertainty, with regards to the shortage list. The material coordinators, buyer/planners, and inventory workers reported that the "mini-MRP" was all that was required for the immediate scheduling needs of manufacturing. The buyer/planners, however, had to consider the other factors in the MRP2 model: longer-term schedules, and longer-term inventory management. The system data showed differences similar to the previous detailed schedule category.

I coded the shortage list as coordinating activities dominated by groups with different beliefs about legitimate MRP2 use. The manufacturing supervisors complained that the material coordinators and the buyer/planners do not use the scheduling information correctly—they always provide too little or too much inventory. The material coordinators claim in the interviews that manufacturing refuses to give schedulers the information they need to schedule more precisely through the full MRP2 model. Though the buyer/planners did not complain about illegitimate uses, other observers in accounting and information systems claimed that buyer/planners would prefer to know more about scheduling through the centralized MRP2 system. All the groups made complaints about the legitimate use of shortage information.

Our final category of failures to use the full MRP2 model at FLEXCO is particularly sensitive: information on how well assembly lines are performing. The scheduling model in MRP2 provides an elaborate standard that can be used to judge how well people and machines are performing. According to the full MRP2 model, one set of performance numbers (corresponding to the "reality" of the factory) should be used through the MRP2 system. At FLEXCO, there were examples of line performance information that were not used through MRP2. Most of this line performance information was tracked by counters and paper tracking sheets on the shop floor. The line performance information was summarized on reports produced on personal computers, and used in cross-functional meetings between planners, manufacturing, and inventory. The specific failures to use the full MRP2 model at FLEXCO are listed in Figure 5.10.

The differences in beliefs about legitimate uses of MRP2 information were especially obvious in the interview data. The two manufacturing supervisors I interviewed both claimed line performance information was mostly for the benefit of others, rather than themselves. Sometimes, in their view, the information needs were excessive, and took too much effort on manufacturing's part. The material coordinators claimed that manufacturing was "afraid" to let true line performance data be made public. This fear made better performance tracking through the MRP2 system impossible. The buyer/planners wanted more information on how well their suppliers were providing quality parts, and expressed amazement that the line performance information they needed wasn't available. Because all of the relevant groups made complaints about illegitimate behavior, scheduling and manufacturing were coded as having different social rule systems with regards to line performance information.

Line Performance *Detailed information on how well assembly lines, assembly areas, and machines are making products.*

Supplier Delivery Tracking
Parts Performance by Assembly Line
Product Count Sheet
Mechanical Counters on Assembly Line
Final Builds Counters
Board Assembly Status Report
Electrostatic Discharge Records
Defects at Rework Station Report
SPC Charts/Andon Log
Defects on Line Sheet with Reasons

Figure 5.10: Line Performance

Both the buyer/planners and the manufacturing supervisors, however, observed differences in technical uncertainty around line performance. The buyer/planners only needed a rough overview of line performance information, to adjust their weekly schedules and choose suppliers. The manufacturing lines needed immediate, detailed, and multifaceted feedback on line performance to quickly find quality problems. Line performance information withheld for minutes could have a drastic impact on manufacturing. The MRP2 systems data did not contradict this coding, for reasons discussed in the direct scheduling example. For line performance, like detailed scheduling and shortage lists, differences in technical demand between scheduling and manufacturing were accompanied by differences in beliefs between groups sharing MRP2 information about how information should be legitimately provided and used.

5.5 Explaining Failures to Use the Full MRP2 Model at FLEXCO

Do organizational differences account for failures to use the full MRP2 model at FLEXCO? Which organizational differences are most important? I used Ragin's (1994) comparative case study technique to examine the pattern of organizational differences between activities coordinated by MRP2 information, as characterized by the three organizational theories. For each major category of failure to use the full MRP2 model, I assigned a '1' to each type of organizational difference (differences in technical uncertainty, differences in outside legitimacy demands, and differences in beliefs about legitimate MRP2 use between activities dominated by different groups), if a difference between organizational activities was seen in the case study data. Otherwise, I assigned a '0', or no organizational difference. Table 5.2 shows the pattern of organizational differences.

Table 5.2: Theoretical Differences between Organizational Activities not Coordinated through MRP2 Use

Information use	Activities coordinated	SCT	INST	SRST
Inventory Details	Scheduling-Inventory	1	0	0
Daily Deliveries	Scheduling-Inventory	1	0	0
Outside Quality Reports	Internal Quality-External Quality	0	1	0
Customs Information	Foreign Inventory-Other Inventory	0	1	0
Lot Tracing	Inventory Across Product Lines	0	1	0
Special Bills of Material	Engineering-Scheduling	0	0	1
Detailed Schedule	Scheduling-Manufacturing	1	0	1
Shortage List	Scheduling-Manufacturing	1	0	1
Line Performance	Scheduling-Manufacturing	1	0	1

SCT = Structural Contingency Theory (Technical Uncertainty)
INST = Institutional Theory (Outside Legitimacy Demands)
SRST = Social Rule System Theory (Schemes of Legitimate Behavior)

1 = Difference between activities
0 = No difference between activities

According to the comparative case study method, the pattern of organizational differences can be reduced to its simplest boolean expression, through the laws of boolean algebra. Simplifying this truth table gives us the equation:

$$\text{INST} \bullet \overline{\text{SCT}} \bullet \overline{\text{SRST}} + \text{SCT} \bullet \overline{\text{INST}} + \text{SRST} \bullet \overline{\text{INST}}$$

(A plus sign represents a logical OR, a 'dot' represents a logical AND, and a line above a term represents a logical NOT operation).

How do we interpret this equation? The first piece of information it gives us is that all three types of organizational difference are needed to account for the failures to use the full MRP2 model at FLEXCO. No one explanation can be eliminated as not having any explanatory power. No one explanation can be eliminated because it is subsumed under another, more fundamental type of organizational difference. All three differences between linked organizational activities, together, do an excellent job of explaining the failures to use the full MRP2 model. All three organizational differences are independent of each other—no one difference requires the presence of any other.

The boolean equation given above summarizes the pattern of differences seen in the data. INST, or differences in outside legitimacy demands, occur only by themselves. What kinds of examples are accounted for by institutional differences? The examples of inventory and quality information not used through MRP2 all satisfied the legitimacy demands of powerful external actors: key customers, and government agencies. Contrary to popular belief (e.g., Powell and DiMaggio, 1991), manufacturing firms are not judged only by the technical quality of their products in the marketplace. Manufacturers also have to satisfy a barrage of institutional demands, insisting that manufacturers perform their activities in a legitimate way.

The data analysis tells us that institutional differences can exist even without differences in perceived technical uncertainty. Institutional differences also can exist independently of social rule system clashes. One might expect that differences in outside legitimacy needs would be associated with clashes that internal groups have over legitimate behavior, but this data suggests this is not necessarily the case.

Both technical uncertainty differences (SCT) and clashes over legitimate behavior (SRST) explain a set of failures to use the full MRP2 model on their own. They do not occur at the same time as outside legitimacy differences, according to the case study data. The technical uncertainty differences by themselves explain two kinds of failures to use the full MRP2 model around the link between scheduling and inventory. Between these activities, a difference in technical uncertainty is not associated with clash between groups over beliefs about legitimate behavior. According to the data, these technical differences are recognized, and accepted as legitimate by all parties, rather than inevitably leading to differences in outlook or orientation between groups as suggested by orthodox organizational theory (e.g., Lawrence and Lorsch, 1967).

Social rule system (SRST) clashes explain one kind of failure to use the full MRP2 model: the use of bill of materials information outside of the MRP2 system. Interestingly, these clashes over legitimate use can, according to this data, take place even without "underlying" differences in task demands (either technical or institutional).

The presence of both differences in technical uncertainty, and differences in beliefs about legitimate behavior, is associated with three categories of failures to use the full MRP2 model. All three of these differences revolve around the connection between scheduling and manufacturing activities. Study 1, reported in Chapter 4, suggested that the relationship between scheduling and manufacturing is particularly prone to conflict and incentive differences. In this case study, these failures to use the full MRP2 model suffer from both technical uncertainty differences and legitimacy conflicts between groups.

What is it about the conflict between scheduling and manufacturing that produces legitimacy differences in the face of technical differences, but not scheduling and inventory? Is it the power that schedulers have over what manufacturers do, due to their control over the schedule? Is it the special sensitivity of information that allows others to judge you and your performance? This data does not answer these questions; it only clarifies the difference. The results may be a result of the peculiar history of group relationships at FLEXCO. It is also possible that the relationship between scheduling and inventory is inherently different. Perhaps their relationship is more narrow, mediated by a simpler information model (the inventory model) that has a less contested basis in shared observations. In contrast, perhaps the relationship between schedulers and manufacturers is more intense and intertwined. The schedulers are the "simulaters" of organizational activity, and the manufacturers are the "simulatees". Both relationships, however, lead to failures to use the full MRP2 model at FLEXCO.

The quality of this case study analysis is limited, of course, by the quality of the data, and the data coding scheme. The coding scheme may seem imprecise, but it is just as or more explicit than case studies considered as models by the Information Systems field (e.g., Markus, 1983). More importantly, it is only as precise as my research required. I was conservative in my coding, only identifying organizational differences when there was what appeared to be overwhelming evidence for them. I was not interested in subtle gradations. I was interested in very obvious differences: weekly vs. hourly information needs, safety regulations vs. no safety regulations, and regular complaints about other group's behavior vs. no complaints. I believe that the resulting data accurately captures the very distinct differences seen in the case study data.

Study 2 examined how well differences between the organizational activities coordinated by MRP2 use account for failures to use the full MRP2 model at FLEXCO. The case study data tells us that all theoretical characterization of differences between organizational activities are needed to explain failures to use the full MRP2 model, and that all three explanations together account for the failures to use the full MRP2 model.

Study 2 compared pre-defined theories of organizations, and their ability to explain failures to use the full MRP2 model given differences between activities. Study 3 looks more deeply at the orientations people have for understanding MRP2 use, for both cooperation and conflict.

Chapter 6
Study 3: How Meanings Affect MRP2 Use

The results from Study 1 also suggested that people's interpretations, or the meanings they attribute to MRP2 use, are an important explanation of when parts of the full MRP2 model are used. Conventional explanations of problems using the full MRP2 model depend on a simplistic view of people's understanding of MRP2 use—as obeying or defying the system, or as maintaining true data versus false data. Study 1 opened up the possibility that people saw their own use of MRP2 in other, less straightforward, ways: as searching for commitments, as providing protection, and as maintaining a reasonable balance between flexibility and external control. In Study 3, I wanted to further analyze people's interpretations of MRP2 use in a real setting, rather than relying on their reconstructions at a training seminar.

After a seven month participant-observer study at FLEXCO, my data analysis pointed to three important sets of orientations, or meanings, that guided people's use of parts of the full MRP2 model. First were people's perceptions of the balance between the work they had to perform and the benefits they received—is this useful for my work? Second, people perceived different levels of trustworthiness in the shared information, and adjusted their efforts accordingly—can I trust this, they asked? Finally, people's use of MRP2 was shaped by their desire to evaluate how well other people and activities were performing, but also by how fairly they thought the system evaluated their own behavior—are others doing good work, and am I being judged fairly? All three of these questions, which MRP2 users try to answer through their actions, force us to build a more complicated view of people's interpretation of using the full MRP2 model than obedience or accuracy.

6.1 Work/Benefit Imbalance: Is This Useful for My Work?

MRP2 use is full of imbalance between the work people have to do to maintain the system, and the direct benefits they receive from using the system. The people of FLEXCO regularly use the idea of work/benefit imbalance to explain their uses (and failures to use) parts of the full MRP2 model. Whether a particular kind of MRP2 use is "good for us and work for them", or "good for them and work for us", the perceived work/benefit imbalance is an interpretation they use to make sense of their information use.

In this section, I will present five examples of MRP2 use that were explained through work/benefit imbalances: work-in-process (WIP) inventory tracking, purchase orders and delivery information, bills of material (product structure information), assembly line performance and quality information, and inventory lot tracing. These examples go right to the heart of MRP2's core data structures: inventory, purchasing schedules, factory capacity, product structure, and accounting. The people of FLEXCO see work/benefit imbalance as integral to their judgments about whether to use parts of the full MRP2 model, and not as a superficial problem that will be corrected with the next software release.

People's perceptions of work/benefit imbalance are rooted in a common story. In their view, certain people are 'busy'. People define themselves as 'busy' to explain why work imbalances in their favor must persist. Conversely, they define other groups as 'busy' to explain work imbalances in their favor (Figure 6.1). At another level, however, 'busy'-ness is used as a generic description of the entire company. Being 'busy', and having a limited amount of time and energy, forces people to select between different 'priorities'. Different 'priorities' lead other 'busy' groups to neglect the MRP2 uses that don't provide them with immediate benefits.

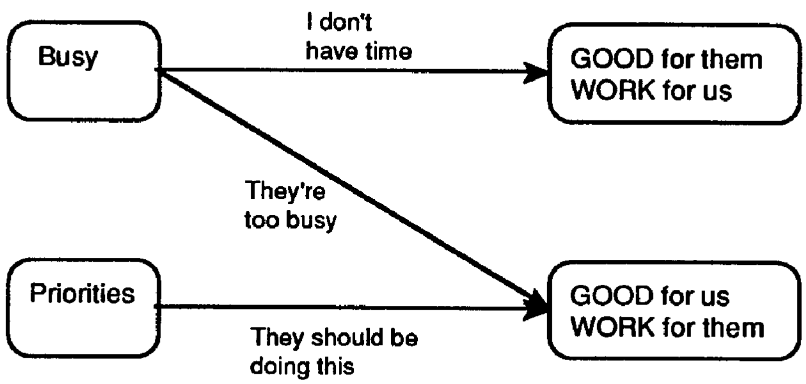

Figure 6.1: Busy-ness, Priorities, and Work/Benefit Imbalance

Being 'busy' is a common explanation for why particular parts of the full MRP2 model are not used:

> **Material Coordinator:** Getting the parts right *has been a problem across the board, in all areas. It's been the direct cause of numerous amounts of downtime. To get it corrected would take an act of God. Everyone's so busy. Part of it is that we keep bringing in new people, new engineers, have to go through a learning curve. We have to make tradeoffs. It's the nature of the company. No one person takes it from cradle to grave. We don't have the people to do it. The workload is too high.* [PRAC.12.38][1]

> **Design Engineer:** *Everyone is so busy, always focused on little things. Even the higher-ups are doing paperwork rather than strategic thinking.* [LOM.15.38]

[1]In all of the quotations used in this chapter, text in *italics* represents the exact wording of the respondents. Normal, non-italicized text is a close paraphrase of the words used by the respondent. (Remember, these quotations are taken from handwritten notes.) My questions to the respondents are enclosed in square brackets. Other notes are delimited by parentheses. The identifier at the end of each quote is composed of a unique code for each respondent or group of respondents, followed by the document number, followed by the line number in the document. All proper names are pseudonyms.

Much of the 'busy'-ness comes from doing work that satisfies others. This work is described as "paperwork" and "bureaucracy". This is their generic description of work that does not achieve their immediate, local objectives:

> **Quality Engineer:** *It's so easy to get bogged down with the mundane. You get so swamped with quality plans, customer requests, that you don't even have time to get out to the line. There's lots of bureaucracy, paperwork, meetings. For a new product, there are lots of meetings, reviewing. You're not helping the people you're supposed to be helping.* [NAM.2.174]

> **Manufacturing Supervisor:** *I always say, paperwork is not one of my fondest things to do. I'd rather be out there, doing things.* [NEH.1.74]

When people are sufficiently 'busy', however, they lack the time to perform what they describe as "bureaucratic" work or "paperwork". With enough 'busy'-ness, they no longer follow the formal "bureaucratic" procedures:

> **Materials Manager:** This place has always been *more hands-on. When the juices are flowing, people don't follow the systems. They're going through stuff.* [SAC.2.59]

In the face of 'busy'-ness—too much work, and too little time to do it in—people interpret the process of choosing which activity to perform as setting their 'priorities'. 'Priorities' determine what people will or will not work on:

> **Accountant:** *Vendor subcontractors, other things are a real mess right now. With our workload, some things you just have to close your eyes on.* [HOJ.3.222]

People and groups are seen as having different 'priorities', which explains why some uses of the full MRP2 model tend to fall apart. In this example, a buyer/planner talks about the difficulty of keeping the MRP2 schedule updated when changes are agreed to over the phone, but people are too 'busy' to enter the schedule change into the system:

> **Buyer/Planner:** *System integrity* is a big priority, in terms of dates and quantities, and a lot of it *falls on the buyer/planner. You say it's OK, but then you didn't update it.* Getting people *to do their own followup, that's a real time management problem.* We've got some *differences in priorities* around here. There was *a lot of friction with follow ups and certain groups.* [RAM.2.152]

Different 'priorities' also affect the work that goes into creating new MRP2 capabilities. According to their explanations, many new capabilities that could be added to the MRP2 system are not because of different 'priorities'—even if the new capabilities are considered a reasonable rather than an excessive request. We see this in the case of a project manager who wondered why a set of reports to track supplier delivery and quality performance, asked for years ago, was never created:

> **Project Manager:** We want to *get to the point where you could sit down with a supplier and show them how they've done. All we're really interested in are the basics, delivery and quality. Have they met deliveries? How many rejected? Number of corrective actions. Straightforward* things. *Nuance comes later.* This *could have been done many years ago.* [CSA.2.23]

In general, there is widespread recognition that differences in 'priorities' are a feature of most organizational activities, including the uses of MRP2. As one example, a buyer/planner discusses the clash between making the purchasing process easy and serving the needs of the production line:

> **Buyer/Planner:** I'm not surprised they're not worried. They have their priorities. We've got our priorities. *If they're ringing this bell over here,* we're over there. I'm not surprised. They're materials. They've got their thing. We've got to worry about the production line. [PB.1.53]

From a purchasing perspective, long-term relationships with reliable suppliers make their job easier. For someone interested in reducing the immediate costs of a production line, a last-minute, high-pressure negotiation can meet their needs at the expense of purchasing's carefully cultivated relationship:

> **Buyer/Planner:** A cable can be two dollars of a six dollar mouse. Or four bucks on a twelve dollar...mouse. *I'm doing it for the product.* If I can get that price, go for it. *It might screw up what Larry's doing, but at some point I don't care.* Especially when you're talking about this much money. Larry, *he'll say they're trying to buy our business. I say, OK! Let them!* And I don't mind *playing hardball* with these guys either. [PB.1.124]

Within this common way of interpreting MRP2 use within the company—as 'busy'-ness and different 'priorities'—we can look at five specific examples of MRP2 use that are seen in terms of work/benefit imbalance. The first example is work-in-process (WIP) inventory tracking.

Work-in-process (WIP) inventory are the parts and materials out on the factory floor. The factory floor is a relatively chaotic place for inventory to be. Compared to a warehouse or final shipping area, more things can happen to inventory on the factory floor: inventory is frequently moved around, transformed into other kinds of inventory, scrapped, and used for completely different purposes. WIP inventory can be tracked at a very fine level of detail, with up-to-the-minute counts and elaborate status information, or it can be tracked using rougher figures and simpler status distinctions. The schedulers, quality engineers, and accountants tend to benefit from very detailed and comprehensive information about where parts are, what operations were performed, and where parts went wrong. Entering and maintaining this information, however, requires more work from the people on the factory floor who assemble and move parts.

FLEXCO had previously done WIP tracking through a module of MRP2. The WIP tracking module, known as R/FLEX, was abandoned six months before my study began. The groups involved in WIP tracking—even the buyer/planners who would have benefitted the most from comprehensive WIP tracking—understood the abandonment of R/FLEX as a case of too much work/benefit imbalance for the people on the line:

> **Manufacturing Supervisor:** *The WIP tracking doesn't buy us much for the work it takes, we didn't have to do that. The buyer/planners are usually pretty much in tune with what's going on.* [ARAC.1.73]

> **Information Systems:** *We used to have R/FLEX, but it required too many transactions, and it had poor data accuracy.* [LED.14.22]

> **Buyer/Planner:** We used to have a backflushing system, and the scrap values were input twice a day. *We didn't get much out of it. It was kind of complicated. The maintenance on it wasn't worth it, and it had a low scrap rate anyway.* [RAM.2.175]

The work/benefit imbalance was seen as particularly severe when conditions were changing quickly. As WIP changes are entered into the MRP2 system, the computer compares the inputs to a model of how certain parts, and in what quantity, should be moving around the factory floor. If the inputs do not match the model, MRP2 complains, and more work needs to be done to reconcile the WIP tracking picture with the current MRP2 model. Particularly as bill of materials information changes, either at the beginning or end of a product's life, the work required by people on the factory floor is seen as overshadowing the benefits to those who track WIP from a distance:

> **Manufacturing Supervisor:** *When it was a high volume operation, it was no big deal. But it became too much work. The quantities issued to us wasn't enough.* [NEH.1.103]

> **Accountant:** *R/FLEX is extremely time consuming.* If you have *a lot of parts, and a lot of changes to the bill, that whacks it out. For R/FLEX to work, you need to have, always need the same standards. But in our business, things change daily.* [Could you give me an example?] *For example, on a changed resistor, they'd use the new one or the old,*

> *depending* on the situation, on the line. *Sometimes they'd use both. It wasn't clean....It was very, very time consuming for the bang we got. We didn't need to see the WIP on the line exactly. A 10 thousand dollar charge isn't that dramatic. Not dramatic enough to hire a transaction entry person for 20 thousand, or another cost accountant.* [HOJ.3.32]

The work/benefit imbalance is even more severe when the benefits of R/FLEX's WIP tracking information are seen as unnecessary by the distant parties. One accountant, for example, talks about the simpler kinds of WIP tracking they used after the abandonment of R/FLEX:

> **Accountant:** *That gives me the ending balance in WIP. I don't care what happens on the line. I don't care what happens within the line.* [HOJ.3.75]

The modeling decisions built in to the MRP2 system about how to track WIP inventory are also seen as affecting the work/benefit balance. In this example, a warehouse supervisor explains why he keeps a separate "tally sheet" of inventory sent to the factory floor. The generic category of inventory movements (or "IAT", inventory transfers) in the MRP2 system does not easily track an important distinction between issues to the factory floor, and returns from the factory floor:

> **Warehouse Supervisor:** *That information isn't up on the VAX.* For instance, the IAT transfer that we use, *it encompasses too many other things, too many different kinds of transfers. Too many variables.* The receiving people *mark it down on the receiver. They collect all the information. It's not real important,* but they do have *different meanings. You want to know how many issues, how many returns. IATs are different. They could be any location-location transfer.* [RCM.2.53]

In their accounts of work/benefit imbalance, some groups were identified by all as having the heaviest work burden. The workers on the factory floor were one burdened group. One of their supervisors explained that there was still pressure to start more WIP tracking on new product lines to help the buyer/planners, but that they were too 'busy' to do so:

> **Manufacturing Supervisor:** *Yeah, they'd probably like it better, but I don't have the time to set it up.* [NEH.1.47]

The warehouse workers were another group whose workload would increase if a very detailed model of WIP inventory had to be maintained at all times:

> **Information Systems:** [A warehouse supervisor] *was the original coordinator* of the R/FLEX project. Poor guy. *He'd wind up reconciling, doing the WIP counts. There's tons of little transactions you have to do.* [LED.22.22]

Even groups who would likely benefit from more detailed WIP tracking also were seen as facing a heavier workload. The accountants, for example, would have more work sifting through the WIP tracking information. An "easier" solution from their perspective is to only track the total dollar value of whole families of inventory types. Otherwise, to keep an accurate count of individual parts, product structure information (or the costed bill of materials, "BMCB") would have to be updated regularly for all parts:

> **Accountant:** [The controller] proposed that we only do the physical inventories every 6 months, and try to track the dollar values. *It's the quickest, dirtiest, easiest way, and the financial impact isn't that great. We'd need another cost accountant or two to do the extra tracking.* [HOJ.3.17]

> **Accountant:** *We're all too busy at this time...For the older parts, which we may have to build 4 or 5 of, their structure has changed dramatically. It'd be nice to do BMCBs to keep it accurate every month. But all I'm worried about is shrinks and pickups.* [HOJ.3.134]

Even with the perceived work/benefit imbalances, which people used to explain the failure of WIP tracking through MRP2, there was a feeling that particular groups would still want to see detailed and elaborate WIP tracking. According to this accountant's story, the buyer/planners would still push for WIP tracking at the expense of manufacturing and the material coordinators:

> **Accountant:** *But we ran into all these problems, keeping the bill of materials right, doing the transactions. You constantly had to adjust everything in the inventory records to keep it perfectly right. It was a lot of work.* [Who would want this?] *The buyers would love to know exactly what's in WIP. It's a black hole. They don't know how much to order. The buyer/planners continually have the material coordinators do semi-physical inventories.* They do it on the tally sheets. The product manager, *he wouldn't care. He'd just say, you'd owe me more people to do these transactions. The material coordinators, they would hate it. They would have to do all these adjustments all the time.* They'd have to do *all this work.* [HOJ.3.163]

The information systems group was impressed with the technical elegance of WIP tracking through MRP2:

> **Information Systems:** *R/FLEX itself works fantastic. It's the ultimate way to keep track of things.* [LED.22.9]

In these stories of work/benefit imbalance, the groups who did most of the work would, if conditions were favorable to them, willingly perform this work. This is how a manufacturing supervisor explained why her group performs their own WIP tracking on a particularly important set of parts, even though they are not required to:

> **Manufacturing Supervisor:** We can only use *these combinations of LEDs and resistors. We count these ourselves, and we count the different combinations available. There are three resistors I can use. Sometimes, a particular resistor is hard to come by. If we always wanted to use one, we wouldn't have too many possibilities. We check the availability of each combo. If I let them run out, there's no one to save me...*[Shouldn't the material coordinators be doing this?] *I'd rather do it myself. Besides, they're glad to get rid of it..* I find out about material problems through the daily meetings. The *buyer/planners may have to do a WIP count* if something isn't clear. *Really, I don't want to do it myself. Only if there's an exceptional commitment* that isn't being met, *then I'll go digging. If it's raw material, they can do it.* [NEH.1.87]

The manual WIP counting done by the factory floor workers is only one example of how groups can do their own tracking, if they see the work/benefit imbalances as more in their favor. In another example, a warehouse supervisor and an accountant created a set of customized MRP2 reports that give a less detailed picture of WIP. According to the full MRP2 model, inventory transactions that have costs associated with them are automatically posted to the general ledger. To avoid constantly trying to reconcile the general ledger with detailed WIP transactions, their reports do not affect the general ledger directly:

> **Accountant:** *This is an off MAXCIM thing, off on the side, for* [a warehouse supervisor] *and cost accounting to get a picture of WIP. We're the only ones that use it. For me, it's dollars. For him, he needs more detail, inventory turns...We don't want it to hit the G/L.* That would mean *more work for doing the adjustment. Later on, we can look and see, do these pictures match? It allows me to have some buffers and not worry about it.* [HOJ.3.182]

In the case of WIP tracking at FLEXCO, we see an attempted use of the full MRP2 model whose failure was widely interpreted as an imbalance between the work performed and the benefits received by different groups. The local attempts to create detailed WIP tracking, disconnected from the full MRP2 model, were also seen as creating a better work/benefit balance.

A second example of MRP2 use seen in terms of work/benefit imbalance are the purchase orders and delivery information. Purchase orders and deliveries are based on a master schedule. Buyer/planners are the people directly responsible for updating the master schedule of part purchases and deliveries. Other groups depend on an updated master schedule: the warehouse must have the latest information on incoming shipments, accountants need purchasing schedules, and quality evaluators need to know whether an incoming shipment is on-time or late. When buyer/planners get 'busy', however, they sometimes neglect schedule updates. And, to reduce the administrative burden of scheduling and correcting purchase orders, the buyer/planners create long-term purchasing arrangement that lighten their workload at the expense of others.

Purchase orders are derived from the master production schedule, which lies at the heart of MRP2. According to the full MRP2 model, the master schedule should show the exact daily amounts to be purchased, every day. At FLEXCO, the buyer/planners "frontload" the master schedule by entering large quantities at the beginning of the month, and no amounts at the end of the month. This frontloading suits their need to flexibly reschedule, but impacts the work of other groups:

> **Buyer/Planner:** *We tend to frontload the schedule at the beginning of the month,* then we *see how it goes.* We take an *overall number* and put it in there. It's somewhat *mentally based. I always have a general idea of what I can build.* [CYB.1.14]

> **Buyer/Planner:** *We tend to front load the master schedule in the system by putting everything into the first week, and then nothing afterwards.* If we didn't have room to maneuver, *we'd be cutting off our nose.* [RAM.3.40]

Any official changes to the schedule require work on the buyer/planner's part, and perhaps official outside approval. The information systems group at FLEXCO created a special program for the MRP2 system ("PODR") that collected all the information needed for an official purchasing change. Running the "PODR" program requires answering questions called for by the official purchasing change procedures. Buyer/planners also had the ability to change the purchasing database directly (through what they called "POODS"). Direct changes to the "POODS" database, for quickly changing a delivery date or quantity, were less work, and would not generate an official change request. A materials manager defended the legitimacy of buyer/planners making direct changes through "POODS" in the name of work savings:

> **Materials Manager:** Yes, they do, and there are *valid reasons* for them

> having access to POODS. *They're able to make a minor change*, say 1 to 2 days in delivery, *without a proper change notice. Sometimes they don't want to write a change notice...Every line item is an order...they don't want to write a change, because every line is an order. They had a legitimate concern* for keeping their ability to do *minor changes to the master.* [APS.8.17]

To other groups, such as the information systems department, buyer/planner behavior was explained by their desire to avoid work for themselves without thinking of the consequences to others, a "quick and dirty solution":

> **Information Systems:** *They just want a quick and dirty solution* to their work stuff. They want to make *quick changes to a PO. They want to do things quickly.* [LED.24.27]

Because of the work associated with creating any purchase order, buyer/planners sometimes form longer-term purchasing agreements (called "blanket purchase orders" at FLEXCO). Longer-term purchasing agreements reduce work for the buyer/planners at both companies, but the lack of specific incoming dates and quantities makes confirming and enforcing purchases more difficult for the warehouse and the factory floor. At FLEXCO, the material coordinators were responsible for making sure the longer-term "blanket POs", or "daily deliveries", were arriving as they should:

> **Material Coordinator B:** [A buyer/planner] *places blanket POs for a year, for a specific quantity. There's no way to track that, though. The system doesn't know what date they're supposed to come in...You don't know how successful you are, compared to if you tracked it through a PO. Blanket POs are easier for the supplier. They have a verbal commitment. There's no hard documentation...*
>
> **Material Coordinator A:** *Most daily deliveries are monthly POs. When you get to the end of the month, you push the balance to the end of next month. You're never past due. Tracking daily delivery suppliers is kind of out there. You're constantly pushing the delivery dates. The blanket POs are a small headache in the back of your neck.* [PRAC.10.185]

But would changes in longer-term purchasing arrangements also require official purchasing changes? A materials manager argued that, again, buyer/planners needed to reduce their work burden by changing the "POODS" database directly:

> **Materials Manager:** *When you push daily deliveries to the next month, I didn't want a change notice issued. I didn't want a lot of paperwork. A fair percentage* of those changes, of those adjustments *are those daily deliveries. It's less work for everyone. They don't need a change order issued.The issue is, do I want a PO change number assigned or not?...The buyers have the need to go through POODS. Plus* [a material coordinator], *I told him* to use POODS *for all the daily delivery changes, so that he doesn't have to go through all that burden.* [APS.8.35]

Other groups, who use the purchasing schedule to determine how well FLEXCO and suppliers are performing, are dependent on buyer/planners updating the schedule in a way that meets their needs. One warehouse worker tells of the difficulty she has in getting the buyer/planners to update the schedule for her benefit:

> **Warehouse Worker:** *I hate this report.* Every month, I take the current forecast 3 months out by transfer dollars. *The buyer/planners enter their numbers...They don't have to update it every time they change the schedule. They don't do a great job with that...All the assembly isn't the problem. People don't get the numbers in. It shouldn't be my job* to tell the buyer/planners please update your forecasting. *I have to send friendly reminders to the buyer/planners, and their supervisors. I have to wait.* Now the managers know, and sometimes I go to them. [HER.1.12]

For those evaluating how well FLEXCO, and suppliers, are keeping up with promised schedule dates, there must be some model of whether FLEXCO or the outside supplier is to blame for a rescheduling. If FLEXCO asked for a delivery to be rescheduled, then the supplier should not be penalized. Keeping track of responsibility for a reschedule requires work, though, and those people might have other 'priorities':

> **Buyer/Planner:** Well, actually, there's probably a lot more supplier responsibility than you might think. Even when we fill in the form for [the administrative assistant], or do it through PODR, the default is [FLEXCO]

responsibility. But we often times don't fill out that part. If it's a change, the whole point is that it's in a hurry, it needs to be expedited. And [the administrative assistant]'s busy a lot of times. Too busy to get our changes in in time. It's a workload issue, a time issue. [PB.1.63]

The distinction between blaming FLEXCO or the supplier for a rescheduling is complicated by another formal procedure: if an incoming part is not sent back to the supplier, no matter what problems it might have, then any problems are attributed to FLEXCO. Under time pressures, however, FLEXCO uses parts with small defects:

> **Buyer/Planner:** The problem is really with how some of the quality data is collected. *Because of JIT, often times we'll use parts that are slightly non-conforming*. If we use it, the system says [FLEXCO] responsibility. If it were supplier responsibility, *you have to send it back*. But they use 90 percent of the parts that have a problem. [RAM.2.125]

The problems with buyer/planners maintaining purchase order information are considered severe enough to explain why the purchase orders and the accounts payable module of MRP2 are not linked together. Accountants cannot rely on the buyer/planners to make their billing easier:

> **Information Systems:** The problem we were talking about was keeping track of standard vs. actual costs. *We're not set up to deal with actual costs. How much we pay has to do with the AP billing. The PO can say whatever price they want. The bill goes into AP, and doesn't hit the PO. The modules aren't closely linked together*. [LED.310.30]

Another group, the warehouse, hoped to encourage the buyer/planners to buy parts in standard quantities by modifying the MRP2 system. Buying in standard quantities would make "detrashing" work (placing incoming parts into standard-sized bins) easier for the warehouse workers. Even though the capability is built into the MRP2 system, the warehouse supervisor sees a work/benefit imbalance as an explanation of why it isn't used:

> **Warehouse Supervisor:** *I had ideas of buyer/planners being able to order in standard lot quantities,* but they haven't done it yet. *We're just using for detrashing in standard lot quantities.* [RCM.1.26]

Purchase order and delivery information was seen in FLEXCO as another case work/benefit imbalance. The buyer/planners were seen as the group who neglected to perform the work that would benefit others. In our third example of MRP2 use, bills of material, the design engineers are seen as the 'busy' group that does not do the work that would help others.

In the manufacturing world, design engineers are infamous for being a breed apart—the stereotype is a highly skilled, creative professional who will not do anything that impinges on their "design freedom". The full MRP2 model depends on an accurate, updated set of bills of material (BOMs) which specify product structure. The product structure information defines how many of each part are needed to produce a final product. Maintaining the BOMs is the responsibility of the design engineer. When 'busy' designers do not update the BOMs in ways that satisfy the other groups dependent on BOM information, people interpret this failure to use the full MRP2 model as a work/benefit imbalance.

From a design engineering perspective, updating a BOM in the formal MRP2 model means subjecting themselves to the dreaded engineering change order (ECO) process. The ECO process creates a lot of work for the design engineer, very little of which is interpreted as benefitting the design engineer (or anyone else):

> **Design Engineer:** *The biggest pain is the ECO process, getting all the sign offs and getting the drafting done. It should take 2 weeks, but sometimes it's been taking up to 2 months because of the workload. Vinny controls the drafter priorities, and he has other hot products coming in. We were discouraged from doing drafting work in the past. But now I do what*

> *I have to. We're all trying to make changes in mid process, up to the last minute.* [LOM.1.16]

> **Engineering Supervisor:** *...Why does it take one month to get the ECO from Ted to you. Jesus! What's the problem? This is so ridiculous.* [LOM.2.27]

There is some recognition that the formal controls in the engineering change process might be beneficial for design engineering, but most likely not. Any benefits to other groups fall under the generic category of "bureaucracy":

> **Design Engineer:** The ECO process *takes one month here, versus 3 days in Japan. In Japan, they're allowed to go and directly modify the paper drawing. That's their official copy. Here, we can't modify it directly. There's a drafter. And there's a 3 person document control bureaucracy. So there's the wait for the drafter, and the official documentation people. And when you make changes in ranges or dimensions, the computer enforces consistency checks, which are good, but they require a lot more extra work.* [LOM.3.8]

The design engineers make distinctions between sections of the BOM that deal with important issues worth spending time on, and sections that deal with trivial matters best left to others. In this example, a design engineer complains that he is responsible for updating parts that a designer should not have to deal with:

> **Design Engineer:** Not so much the number of levels. *The biggest pain is messing with all of the packaging materials on level 2. It's just boxes and stuff. Why do I have to spend so much time messing with it?* [LOM.2.19]

> **Design Engineer:** *I'm not a secretary. I'm not taking care of the paperwork. I don't care if they get paid or not.* [GNE.2.17]

The design engineers are also understood as not approving of the MRP2 system, which makes them even less willing to work on maintaining the BOMs:

> **Accounting:** *In fact, they're meeting today about a problem with documentation.* You see those numbers at the end of the part number, dash 001, 002? Those are new rev codes. *They want to do a mass change from A to B rev level,* but the system won't let them. *The engineers don't like it too much. Actually, they don't like to deal with anything. They just want to invent wild stuff that can do amazing things.* [HOJ.5.157]

Other groups depend on the design engineers to maintain the bill of materials information in a way that meets their working needs. The buyer/planners, for example, cannot automatically schedule purchases through the MRP2 system without having the latest product structure information. Because of the lack of work on design engineering's part, buyer/planners find their own ways of getting the information they need:

> **Buyer/Planner:** Take the BOM. It's *used by a number of people. The BOMs are volatile,* or at least the *development BOMs. Documentation is slower than knowing.* [CYB.1.41]

The factory workers need to know which parts should be used to make a product. They interpret their inability to get the information they need from the MRP2 system as a 'busy'-ness issue:

> **Manufacturing Supervisor:** In this area, we've set up sample PCBs with all the part numbers, so operators know what they should look like...*The way we used to do it, we had to add all the part numbers.* Now, I *just take a board and copy the part numbers from a spreadsheet. If our design engineers had the time and inclination,* they could do it for us. *But they're so swamped I wouldn't even ask.* [NEH.1.179]

For the quality engineers who also must know product structures, the BOMs in the MRP2 do not meet other specialized working needs. In this example, the quality engineer assumes that design engineers are obviously too 'busy' to update BOMs properly, but blames the buyer/planners for not spending as much time on BOMs as they should:

> **Quality Engineer:** The BOM is OK. The drawings have a revision

> code, and a supplier for each part. Each part has a buyer/planner watching the engineering changes. But sometimes, *because of the paper mill*, buyers will *sign without checking* as carefully as they should. Specialized things like flammability ratings are *not in that loop*. Others are *not as concerned* with those issues. [NAM.1.32]

The use of part numbers is also seen in terms of work/benefit imbalance. To make his work easier, a quality engineer tried to make certain ranges of part numbers meaningful for his work (in this case, the parts that have been approved by outside quality laboratories). Preserving the meaning of these part numbers, however, requires the cooperation of the design engineers—when they assign new part numbers, they must pay attention to the quality engineer's numbering scheme. A more elaborate part numbering system was used in the past, but was abandoned because of what the quality engineer saw as a work/benefit imbalance:

> **Quality Engineer:** *I wanted to put a flag in, whether the part was agency approved or no. But MIS hasn't had the time in the past one and a half years to do that. So I found a different solution. I created a whole new part number. The prefix is 825, just for the parts that have agency logos. Documentation uses the prefix 824 for another group. That way, MIS can run me a report on those part numbers. It's oblivious to them...We try to limit it, though.* We used to have a more complicated system. *We tried to differentiate each part* based on its characteristics. *But the engineers spent too much time on it. They didn't know which ones to assign...*We're supposed to have different part numbers for screws, depending on what kind of threads they have. *As it is, engineers have a hard time finding prefixes for a screw. But it helps when I sort.* [So having a strict part numbering system like that is a lot of work?] *Yeah.* [NAM.2.19]

The quality engineer also depends on design engineers filling in useful descriptions of products in the bills of material. Again, because of their 'priorities', the design engineers do not take the time to make the quality engineer's work easier:

> **Quality Engineer:** *Sometimes, the descriptions aren't very consistent. See the description field in here? It's been kind of random. This one says FCC label. It's really a product label. The FCC information is just part of that. Sometimes I'm trying to find parts, and I can't find them by*

description. I do search that way sometimes. [NAM.2.43]

Our fourth example of MRP2 use seen in terms of work/benefit imbalance is assembly line performance and quality information. Many groups within FLEXCO demand information about how well the assembly lines are performing—how many products are being successfully produced, and with what quality. The work/benefit imbalance is seen as a tension between the simple information needs of the manufacturing workers, and the more elaborate needs of outside evaluators, such as material coordinators and quality engineers. Fulfilling the information demands of others adds to the manufacturing workload, and constrains their ability to meet their immediate work needs:

> **Manufacturing Supervisor:** Almost at each machine, we have sheets to track the performance of parts running down the line. My line leads and I collate these into a monthly status report, which I send to my boss. I need *something simple for me to use. I often use the computer to whip out quick, simple forms. A lot of times I try something quick and dirty.* [NEH.1.11]

Much of the assembly line performance information is created through pre-formatted paper forms and mechanical counters. A manufacturing supervisor explains why this information is not used via MRP2 as a work/benefit imbalance:

> **Manufacturing Supervisor:** *New forms are done mostly with Excel. This one Mike did.* We converted the line from an old product, and some of the stations have had new kinds of problems since the conversion. *For every subgroup of 200, we write down the performance at this machine. Another form I made up for laser trim verification, to check to make sure that all are OK. Yeah, I've gotten clever over the years.* In this next area, we use the same data sheet, but we *don't have much time to fill it in. For cosmetics, we needed a better idea. With quality engineering, we worked on a more complicated form,* with the different defects already written on the form. Also, *we gave her a multiple counter, a physical counter.* [NEH.1.24]

Other groups, such as the material coordinators that do detailed line scheduling, ask for their work to be made easier. The material coordinators say they would benefit from having a computerized MRP2 system create more elaborate daily production numbers:

> **Material Coordinator:** *I'd like to see more computer controlled production. I'd like to see dailies, with actual headcount numbers. To churn out this data and start analyzing it.* [PRAC.10.135]

Sophisticated data analysis, however, does not meet the working needs of the factory floor. For their work, they told me, their information needs are simple, and are already met with their current, non-integrated systems. Even the statistical process control charts (SPC) on their wall, which manufacturing experts would see as a very simple analysis tool, are seen as a bit elaborate:

> **Manufacturing Supervisor:** *It's printed out at the rework station. Any kind of trend you'd find right then and there.* The trends are recorded on this SPC chart, *but usually we don't even have to look if they're giving us the information they need.* [ARAC.1.94]

Assembly line performance information can be used as quality information, if the production counts also include the reasons for why the parts that weren't made failed. Recording detailed reasons for defects, according to a classification scheme that makes quality engineering work easier, adds to the workload on the factory floor. Quality engineering produces its own reports (called "PSRs"). The manufacturing supervisors explain how much quality information they are willing to create as a work/benefit imbalance issue:

> **Manufacturing Supervisor:** Now, we *may not need to react if there's a trend only*, and it's not out of control. But the PSR is different. It's tuned *to quality*. Quality does the report. It breaks down causes, and records the major and minor defects. Each kind of product has its own PSR. [ARAC.1.117]

> **Manufacturing Supervisor:** Line leads do their sheets daily, do their

> daily product counts.*Quality* needs this information *quite a few times. What percentage. How often it comes. If it gets more complicated than that, I kick it back at them. That's the usual. But we don't always have the time for it.* [NEH.2.57]

The quality engineers work hard to produce the "PSR" reports, which analyze long-term quality trends. But do manufacturing workers or buyer/planners use their reports? Not according to the quality engineers. According to his interpretation, they would like to use the quality reports, but they are too 'busy'. Instead, "PSRs" are used to show outside customers and suppliers that FLEXCO has a sophisticated quality system in place:

> **Quality Engineer:** *That's been at the heart of a lot of the frustrations. We put the data on PSRs, process summary reports. After the data is input, it's filed away. We generally use it as a sales tool. We have a really good dog and pony show for potential new suppliers...We use it as a sales tool. It gives customers comfort* to know that we have these systems in place. *We tried to have meetings to discuss it, but it didn't work out.*
>
> [Do they still have these meetings?] *I'm not sure. The data's a week old when they see it. It helps to look at major trends, to see what the major trends are...How much are they using it? We haven't been completely effective with getting them out of the numbers mode. They want to, but so many other things come up.* That makes the PSRs *kind of like an afterthought.* [NAM.2.137]

In the example of assembly line performance and quality information, much of the work burden fell on one group, the factory floor workers, for the information benefit of others. In our last example of perceived work/benefit imbalances, inventory lot tracing, the burden falls on the warehouse workers.

Lot tracing requires that detailed information be kept on parts: what supplier it came from, what exact shipment, and what operations were performed on them. If an assembly line needs a widget, the warehouse worker cannot just grab any widget on the shelf. They must ensure that the widget comes from the appropriate lot, and that the lot tracing information goes with it.

Lot tracing information was kept on a number of safety-critical automotive parts. The lot tracing information was kept on paper forms, and on a local area network that was separate from the MRP2 system. Keeping the lot tracing information separated from MRP2 was explained as the automotive group keeping parts for their own benefit:

> **Buyer/Planner:** Some of the groups are keeping other data *for their own benefit.* Automotive, they track lots off line because of their *strict safety rules.* [RAM.2.140]

> **Manufacturing Supervisor:** On the automotive line, *you need to have quality people. Not that we don't need quality people, but the clockspring is a life and death thing. They have to trace lot numbers. We do some serial number tracing, but that's just the tip of the iceberg.* [The clockspring manufacturing supervisor] *generates a lot of paperwork.* [NEH.1.145]

Lot tracing means more work for the warehouse, with little direct benefit for them. In their terms, lot tracing is a "pain in the ass":

> **Warehouse Supervisor:** *Sure. It's not that much extra work. But actually, lot tracing is a pain in the ass...*If it's lot controlled, you can't just take any parts. You cannot transfer 500 from one lot to another. You'd have to adjust down the lot number to do that. *You have to pay attention to which lot it's coming from.* [RCM.5.16]

In the discussions of work/benefit imbalance, there are also groups who see lot tracing as not creating any more work for themselves. There are groups who gain, and groups that lose, but there are groups who perceive their work as not affected by lot tracing:

> **Accountant:** *Lot control or no lot control, it's all the same. Because I have it on the system, I don't have to worry how many products we have.* [HOJ.3.214]

> **Design Engineer:** [Does the extra information help you?] *No. All we*

> *really care about is if the processes are under control at the time, and that quality parts are coming off. It doesn't help us. It's strictly for liability.* [LOM.10.31]

> **Material Coordinator:** *It means more work for the material handler. They have to get the right lot number. And enter the lot number on the LAN. It's more work for them, but it doesn't impact us at all.* [PRAC.10.166]

Besides those groups that directly benefit from lot tracing (mostly the automotive managers who must satisfy outside safety regulations), there is a distant group who considers lot tracing as an elegant technical solution: the information systems group. They might dream of lot tracing for every single part, even if they recognize that the work/benefit imbalances make it impractical:

> **Information Systems:** Really, the only real solution here is to do *lot tracking on every part issued.*
>
> **Quality Engineer:** *Things are headed that way.*
>
> **Information Systems:** But hey, please, *don't let it get out of this room that I suggested lot tracing for every part*...[The warehouse manager] *would strangle me.* [GMS.10.11]

FLEXCO attempted another kind of lot tracing for their "free trade zone" project. The accountants suggested that FLEXCO try to reduce their import taxes by tracing imported parts that were used on in products that would be exported outside of the U.S. According to "free trade zone" regulations, FLEXCO would not have to pay import tax on parts they could prove were shipped out of the country again. The benefit for accounting would be balanced by an increased workload for the warehouse, who would have to keep "free trade zone" and other parts separate. The warehouse uses a workload explanation of why an entirely new lot tracing system would have to be set up for the "free trade zone"—linking to the old systems would, again, be too much of a "pain in the ass". Ironically, even though this project will create more work for the warehouse, the supervisor is excited that he gets to work on a new project rather than his normal routine:

> **Warehouse Supervisor:** *For every finished good* we include in the FTZ project, I have to download a bill from the system and create a list of parts with codes, sort of a *mini-bill*...[How about linking FTZ to lot tracing?] *Nah. We could have done it by item part master, or by lot number. Lot number is enough of a pain in the ass as it is.* [How's the project going?] I'm not sure. *I'm flying blind on this thing. Our attorney has given us some things that we should be tracking, but I don't really know. I love working on this stuff. I haven't been at my desk in days.* [RCM.3.17]

Lot tracing was the fifth and final example of an MRP2 use seen in terms of work/benefit imbalance. The groups involved explained their uses of lot tracing information as for their own benefit, as work for others, and as neutral parties that were unaffected.

In this section, I have presented five examples of MRP2 uses that were understood by the people using the system as work/benefit imbalances between groups. The balance between work performed and benefit received is a concept that FLEXCO workers use to explain when parts of the full MRP2 model are used or not used. Work/benefit imbalance is a crucial concept they use to determine for themselves how they should share, and use, production planning and control information.

6.2 Trust: What's Real Here?

People do not perceive all MRP2 information as equally trustworthy. What can I trust?—what's real here?—is a question whose answer affects how people perceive MRP2 uses, and which uses they are willing to participate in. Determining what is real, what can be trusted, requires work. In this section, I show how people at FLEXCO interpreted the work required to establish trustworthiness, and discuss three different types of work they identified in their stories of MRP2 use: determining accuracy, working on faith, and assessing the system.

For the people of FLEXCO using MRP2 information, determining what's real, and what isn't, requires work. According to their interpretations, they classify significant amounts of their time as spent "checking", "making sure", and "investigating". In this example, a buyer/planner checks to make sure parts that are classified as "not used" (NU) are truly not used by any existing product line:

> **Buyer/Planner:** When I get a bill, *I'll check on all the NU's just to make sure it's true. I'll also check the parts with the other codes, to see which program has the largest usage, which program will have buying responsibilities.* [CYB.3.20]

The perceptions of trustworthiness, derived from past experience, guide their use of the MRP2 information. In this example, a material coordinator engages in investigation work, even though the information turns out to be trustworthy enough for his purposes:

> **Material Coordinator:** Now here, on the system, this what if tells me what I've got. *I need to make sure these parts are here. For instance, I know that number's not right* (pointing to the screen). *It's not enough. This report won't pick up two lines. See?* (He calls up another screen). *Oh, well, it is right.* [PRAC.12.200]

Investigation work—seeing what's real—is seen as necessary for untrustworthy information. Investigation work allows a person to determine if information is "reasonable" or not:

> **Accountant:** The bill, the highest level item cost, was frozen for 6 months, *but that's another story. A lot of times they mess up the bill of material,* then we have to *investigate and see if that's reasonable.* [HOJ.3.29]

Investigation work determines that information is trustworthy, but there is also a belief in these accounts that work is needed to keep information trustworthy. If you don't "stay on top" of trustworthy information, it will "go to hell":

> **Quality Engineer:** You know how it is. *With computers, what comes out is only as good as what goes in.* For instance, we've got everything on a database for the ISO audit, all the action items. *I left it dormant for awhile*, and it went to hell. *That's what happens if you don't stay on top of it.* [NAM.2.13]

Establishing trustworthiness is important enough that whole jobs are seen in these terms. According to this warehouse manager, the reason for having material coordinators is to preserve the trustworthiness of the buyer/planner's picture of the factory:

> **Warehouse Manager:** An important part of my workforce are the material coordinators. *They are the eyes and ears* of the buyer/planners, keeping track of what is actually happening in the warehouse and on the floor. [LLA.1.14]

Figuring out what's real is important because shared information may be based on something that's not considered real. Many of the key data structures of MRP2—including product structure, production schedules, and inventory—are negotiation points between groups, and with the outside world. In the bills of material, for example, some parts are considered "unnecessary" by certain groups, and thus are less trustworthy. Finding out which parts are real or not guides how they use the system:

> **Design Engineer:** When you get things from them, *there's always extra unnecessary specs in there. You have to be able to negotiate with them. You need the skill to figure out which are the real specs.* [LOM.3.24]

The production schedule is notorious for including information that may be untrustworthy.

In these accounts, the users of MRP2 have to determine which parts of the schedule are real, and which are not:

> **Materials Manager**: I can't believe what I've just been hearing. *We've been screwed on* [Company A]. [Company A] *was supposedly a done deal, for 120 K.* We go ahead and invest hundreds of thousands in tooling to produce the things. Then [name of competitor] *undercuts us. We thought we were fat and happy*...Luckily, we *might have fallen into some* [Company B] *business, 20 K or so mice to take up the slack.* The [Company C] keyboard *came from nowhere in the last couple months*, and now they want 30 to 40 K, all in the last month. [Product name] has been postponed from January to September. *I don't know what's real anymore until we build. It used to be when the funds were let go, it was real. I have a sales forecast now that means nothing to me.* [GMS.2.51]

The workers at FLEXCO interpret some uses of MRP2 information as strategies for determining what's real, and for protecting themselves against untrustworthy information. One strategy is to create and use information locally, as in this case of defect information on the shop floor:

> **Manufacturing Supervisor:** At this testing station, the defects are recorded and printed out right here. *It's printed out at the rework station. Any kind of trend you'd find right then and there.* [ARAC.1.94]

Another strategy, for the more technically adept, is to create many customized information sources. These customized views are created because of the "protection" they give the person from untrustworthy shared information:

> **Accountant:** [How many different spreadsheets do you use in your work?] *About 100. I've got a lot of different snapshots. I've done hundreds of Xentises, for inventory adjustments, standards, analyzing standard cost rollups,* and all kinds of other stuff, *to protect myself.* [HOJ.5.139]

Determining what's real, what information can be trusted, is the justification people use for why investigation work takes place. The work that goes into determining trustworthiness is divided by the people themselves into at least three types: determining accuracy, working on faith, and assessing the system.

The first type of trustworthiness work, determining accuracy, sounds like the old MRP2 problem of not having accurate information. In these accounts, however, 'accuracy' is not a fixed property that information does or does not have. 'Accuracy' is something that has to continually be determined. Determining whether the 'accuracy' of the information meets a particular work need is a problem that must be continually solved by the people using MRP2 information.

In their accounts of MRP2 use, inaccurate information is a widespread problem. People have to constantly evaluate their trust in the information, and do:

> **Accountant:** The BOMs aren't accurate...*Most of the bills are wrong.* [HOJ.1.26]

> **Accountant:** They have another file that tracks first articles. *But yeah, the MRB database is really bad.* [HOJ.5.170]

Usually, their assessments of how much MRP2 information can be trusted are not as stark as 'accurate' or 'inaccurate'. Even in the examples above, the respondents agree that much of the information is usable for some important tasks. Trustworthiness can be conditional, or partial:

> **Manufacturing Supervisor:** *The BOM is only changed by engineers. You could print it yourself. It's updated fast enough, once it's established.* With new products, it's like *this might not work. Those I never trust.* [NEH.1.115]

> **Quality Engineer:** *The data is good, but 10 to 15 percent of it is questionable.* [NAM.2.156]

> **Materials Manager:** Tracking the daily deliveries, the ship to stocks, that's all being done manually. *It's not accurate. It's not always supplier responsibility.* [GMS.1.19]

> **Quality Engineer:** There's 25% inaccuracy on this report. Pieces are *physically there, but they're not entered during the first article review.* [GMS.2.9]

Other kinds of MRP2 information are perceived as being sufficiently accurate:

> **Buyer/Planner:** *I like working with the boys. The MRP is pretty accurate, the due dates are accurate. The inventory accuracy is 99.8 percent. That's pretty rare. I haven't had an inventory adjustment in the past year.* [RAM.2.99]

The accuracy of information can change over time, requiring a new assessment of trustworthiness. Untrustworthy information can become trustworthy, due to someone's actions. In this example, the institution of a new quality procedure changed a buyer/planner's assessment of how 'accurate' engineering drawing are, the first time a part is purchased:

> **Buyer/Planner:** *We have to have real discipline with engineering, and with ourselves. 9 out of 10 first time buys, you don't have a drawing. The lead times had to be shorter than the documentation cycle. But with ISO, you have to have that drawing.* [RAM.2.201]

Closer to the factory floor, material coordinators have a term for the work they must do to evaluate how much they can trust information from distant sources. They call it "sanity checking":

> **Material Coordinator:** *The* [keyboard code name] *line is down right now, because of a shortage. We need something to do sanity checks for information going into the system. When a new product hits the floor, 90 to 95 percent of the time something's wrong. In this case, it should have been two per, instead of one per. We got blindsided by that.*

[PRAC.12.23]

Information that continually falls short of meeting the work needs of material coordinators, that requires continuous "sanity checking", also has a name. They call it "the black hole." Removing the "black hole", by increasing the 'accuracy' of the MRP2 information, would allow the material coordinators to "see" more clearly:

> **Material Coordinator:** *Take away the black hole, so we can do it from here without getting up. It would cost only 50 to 500 dollars. And we could save a lot of man hours, just from doing the sanity checks. Everybody'd have a better picture.* [PRAC.12.160]

To the material coordinators, a logical solution to their trustworthiness problem would be to enforce restrictions on entering information through the MRP2 system itself. That way, the need for "sanity checking" would be reduced by not allowing others to enter information that doesn't make sense for their uses (what he calls, in this example, "bogus" information):

> **Material Coordinator:** *The system should not allow you to put in bogus information. In some places you can enter information and have the system say it's no good. I know the capability is in there. It shouldn't allow it. Don't let them redefine the structure. I know it's possible, because on some key caps it automatically kicks up warnings if you don't put in the right ratio of plastic and resin. Take away the opportunity for error.* [PRAC.12.51]

The work involved in determining accuracy is complicated because a shared information resource can be used for multiple purposes. In this example, a material coordinator queries the MRP2 system to determine how many resistors a product has. When the answer is a fractional amount, rather than a whole number, the information does not make sense for his particular purposes:

> **Material Coordinator:** Let me show you the where-used inquiry, that should make us avoid situations like this. This shows how many parts for each finished good. [Why are there fractional quantities?] They're trying to keep track of something. *I wish they wouldn't do that.* [PRAC.12.31]

At other times, in these accounts, groups may seek to simplify the work they do, at the expense of data 'accuracy'. Providing detailed inventory information, for example, requires work on the part of warehouse employees:

> **Warehouse Supervisor:** *But it's more difficult in maintaining the accuracy. The guys have to pull from a specific box with a specific lot, not just any old box with the part number. They have to pay a lot more attention...You've got to keep on their ass. They have a tendency to go get this part number rather than looking at every thing.* [RCM.5.80]

> **Information Systems:** *We wanted to simplify the process of inventory control, even at the expense of inventory accuracy.* [LED.22.19]

These examples show that MRP2 users at FLEXCO define a category of work that determines the 'accuracy' of MRP2 information. Their assessment of the 'accuracy' of MRP2 information guides their use of MRP2, and requires continual effort. I label a second category of trustworthiness work as 'working on faith'. 'Working on faith' has to do with their belief that key pieces of the MRP2 information model are agreements between people, or assumptions about the future. The "commitments" entered into the MRP2 system as, for example, future scheduling dates, are seen as having different amounts of "reality". The people using MRP2 see themselves as having to determine how real these "commitments" really are.

In their explanations, people claim that time and resource constraints force them to enter speculative information where, strictly speaking, the MRP2 model expects solid facts. As the higher level managers explained, FLEXCO cannot afford to wait until everything is perfectly known before entering "commitments" into the system:

> **Project Manager:** *We're doing a lot of the work on faith, before a formal PO comes out, based on existing relationships.* Getting a PO sometimes *isn't the fastest process.* [CSA.2.37]

> **Materials Manager:** We have 12-14 week lead times on many of our computer products. Customers can't always give us that much warning ahead of time. Often, *we have to place orders for them in the system* before we get the official order. That's reality. We have to *share the risk. Every major account does this.* [SAC.1.23]

> **Materials Manager:** The standard 12 week lead time is really a *negotiation point. It's almost never recognized.* [SAC.2.12]

'Working on faith' requires making what the buyer/planners see as "educated guesses" about what "commitments" make sense. As an added complication for those who have to evaluate the trustworthiness of the "commitments", the "guessing" that goes on has varying degrees of illegitimacy. The information entered 'on faith' may not be known to everyone, as in the example below. The buyer/planners have not told FLEXCO headquarters about the real extent of the "educated guessing" that goes on around the sales forecast:

> **Buyer/Planner:** Our lead time is about 90 days. 90 to 120 days out, our forecast is *about 35% accurate.* But our schedule *doesn't change that much, except for a few notorious suppliers...The second guessing we do is more accurate than the forecasts.* We know more about what's going in. [Do the [FLEXCO headquarters] people know this?] *They don't know that the second guessing is going on.* [RAM.2.65]

There are differences in the amount of faith people place in these MRP2-based "commitments". In this example, the trustworthiness of a scheduling "commitment" depends (unofficially) on the past credit history of the supplier:

> **Buyer/Planner:** [Company A] and [Company B], *we order to forecast. On* [Company C], *we can't. They've had credit problems. The check has to be in the bank before we'll start a* [Company C] *order. That means we*

lose lead time. [RAM.3.30]

The trustworthiness of these "commitments" has to be re-evaluated when situations change. In these examples, FLEXCO employees describe how changes in production schedules change the value of particular "commitments":

> **Buyer/Planner:** And we're trying to *keep the schedules real.* There's always supplier slippage. [RAM.2.131]

> **Design Engineering Manager:** (Heard from the General Manager's office, loudly spoken.) We reserved 46 thousand, and now they don't want it! [GNE.2.20]

When 'working on faith' through MRP2, there is work involved in making sure that people live up to the "commitments" entered in the MRP2 system. Preserving scheduling commitments with suppliers, according to buyer/planners, requires work:

> **Buyer/Planner:** [What about schedule changes?] We try not to. *Major schedule changes have a way of coming back to you.* We've got a decent *check and balance system* here. We've got to make sure that suppliers *meet their commitments.* [RAM.2.46]

The "commitments" are not just with the outside world. "Commitments" within FLEXCO also require work to be preserved, and have to be investigated for trustworthiness. For these reasons, according to the buyer/planners, changes to the master schedule are discouraged by others:

> **Buyer/Planner:** If I reprioritize something, I have to reconcile it with Barbara...*There's a lot of pressure here to keep up the master schedule.* [RAM.2.87]

> **Buyer/Planner:** *System integrity* is a big priority, in terms of dates and quantities, and a lot of it *falls on the buyer/planner. You say it's OK, but then you didn't update it.* [RAM.2.152]

To other groups, 'working on faith' comes perilously close to "lies". According to a material coordinator, "commitments" entered into the MRP2 system can remain even after the responsible parties know it is no longer in force. Evaluating and correcting problems with a purchase order "commitment" takes work on their part (i.e., coping with the "bureaucracy" of a "request for action" procedure):

> **Material Coordinator:** If there are problems with a PO, *we'd have to walk it through with an RFA. It could take 1 to 6 weeks, if not longer. We had some that never got fixed. But it's up to them to get it here on time. We don't put a PO on the system and lie to the system.* [PRAC.12.196]

When other groups challenge the "commitments" made in the system, it is interpreted as a sign of mistrust. Change requests from FLEXCO headquarters are seen as showing their lack of trust in the buyer/planners:

> **Buyer/Planner:** We get 4 or 5 changes a day from them. Most are just changes in shipping. Still, *it breeds a bit of distrust. Some individual challenging what we're doing*. [RAM.2.84]

Within FLEXCO, trustworthiness judgments are made about people as well as information. People are defined as being trusted enough to make certain types of "commitments". The trustworthiness of the person is another factor to be evaluated when determining the trustworthiness of a "commitment". In this example, an accountant explains how he is trusted to make account adjustments that people in his position ordinarily would not have the authority to do:

> **Accountant:** *Most of the information, normally the controller, would have more of this information. Because it's easy for me to do, I download it. He can trust me. Most of the stuff is confidential, but we move so quickly. It wouldn't affect anyone anyway.* [HOJ.3.116]

In this second category of trustworthiness work, 'working on faith', we see how complicated judgments about the trustworthiness of "commitments" guides people's uses of the MRP2 system, and the extent to which they must work to guarantee trustworthiness. In our final category of trustworthiness work, 'assessing the system', FLEXCO employees assess the information system itself. What will technicians allow on their system? How does the system work? What work will the technicians help them with? According to FLEXCO employees, they must constantly engage in an effort to determine how much the information system itself can be trusted to meet their working needs.

In assessing how much the MRP2 system can be trusted to meet their needs, groups evaluate the objectives of the information systems people. The information systems people are seen as the gatekeepers of what will or will not be a part of the MRP2 system. For a warehouse supervisor trying to decide whether to link a new inventory tracking project to the existing MRP2 "mainframe" (actually, a VAX minicomputer), he feels he must know what the objectives of the information systems group are:

> **Warehouse Supervisor:** *I'll do an off-line one. I thought that* [the new IS worker] *would do an item master, and I'd do the Xentis.* When the parts came in, *maybe in receiving, there might be an extra prompt* on the system. But *I don't know what* [the controller's] *objectives are for the mainframe.* I guess he *doesn't want to screw it up. I don't know.* [RCM.2.112]

When the warehouse supervisor receives news from the MIS director (who is also the controller) that the new inventory tracking project may be cancelled altogether, he expresses his frustration. The accountant, however, uses the changing circumstances as an explanation of why the project should not be linked to the minicomputer—the project is not stable enough, or trustworthy enough, to risk jeopardizing the critical MRP2 system:

> **Warehouse Supervisor:** *God, I'm so frustrated. Am I supposed to be the one making these decisions? Now* [the controller] *says, we're only*

> *going to track this many parts, and it might only save us 10 K. Why didn't he think of this six months ago? Those folks are supposed to be thinking about this. What exactly do we need?*
>
> **Accountant:** *That's exactly why we don't want this on our system...* [RCM.10.20]

Assessing the trustworthiness of the information system requires investigation work, because other groups feel they do not understand why the system works the way it does. They do not understand why some capabilities are added to the system, and others are removed:

> **Materials Manager:** We need a *proactive MIS group*. We should be able to get all the upgrades for the system. They should know the DEC system better. There should be more linkups with suppliers. Before, we used to be able to send faxes directly from email. Now that's been taken out. *I don't know why, or when it's coming back* [SAC.2.42]

Other groups describe their lack of understanding of why system changes take place as a trust issue. For projects that have been worked on for years without success, such as the quarterly evaluation of suppliers, a material manager wonders what can be trusted:

> **Materials Manager:** I mean, take a look at this quarterly report card thing...*There's no control here. I'm not going to put this on my objectives. What's real here?* [SAC.2.75]

In addition to varying levels of trust in the stability of the MRP2 system, there are also varying levels of trust in people's understanding of how the MRP2 model really works. Groups using MRP2 interpret their lack of systems understanding as another trust issue. In this example, users of the MRP2 see themselves as wanting to learn about the MRP2 model, and wanting to trust the system, but not being able to because of a lack of assistance from the information systems group:

> **Quality Engineer:** Why can't we *have it read the part number and the receipt date*. [The new IS worker] *says it can't be done. Where's the lot? Why can't it be done?*
>
> **Purchasing Manager:** I want to know *what happens in the system once the data's entered.* (He gets up, starts drawing on the whiteboard, raising his voice.) If the report shows this, why? *If you do an operator error, what happens?* Can you explain to me why these reports are so difficult?...well, please, find out why this is so hard. If the data is going into the system here, here, and here, why can't we get the report? The data is in there.
>
> **Quality Engineer:** [Employee name] is the one who inputs the MRRs, and says whether it's [our company] or supplier responsibility. There might be a problem with the logic of the program. *No one explains to us the logic of the program, or the logic of these formats.* [GMS.1.54]

The interconnections within the MRP2 model complicate the assessment of trust. People using the MRP2 system interpret some changes in the system as coming from nowhere, requiring them to reassess their level of trust again. For this information systems worker, their lack of trust is simply ignorance:

> **Information Systems:** *I fixed the report for them, and now the others are all wrong. Of course they're wrong. The data's been wrong since the beginning of time. They don't realize that it's all connected. That it's all linked together.* [LED.16.8]

Finally, the users of MRP2 constantly assess the information systems workers as part of their 'assessing the system' work. People using MRP2 assess the technical skills of the information systems workers, their priorities, and their political interests. During my study, the information systems group hired a new IS worker from the warehouse. Their intention was to hire a person with more real-world business experience, but that lacked technical experience in the short term. Other groups accounted for their cooperation (or lack of cooperation) on new MRP2 systems projects based on their low trust in the technical skills of the new IS worker. The IS workers realized that they were being constantly assessed:

> **Information Systems:** [How did you learn to do all this?] I picked it up. I've got my *book of tricks* up here. *Things aren't documented. It's pretty hard for people like* [the new IS worker] *to come in and learn what's going on.* [ERG.3.33]

> **Information Systems:** I think someone *coming in fresh* would be really helpful, because it has a lot of history behind it....No problem. *Ignorance is my forté.* I'm the first to admit that *I still have a long way to go* on learning these skills. [LED.5.8]

> **Accountant:** *But they do want to kick* [the new IS worker] *off the project. They think he doesn't know what he's doing.* [HOJ.2.16]

Because the information systems group had limited time and resources, other groups assessed the trustworthiness of parts of the MRP2 system by judging what the priorities of the information systems group were. Often, their priorities were not on the existing MRP2 system:

> **Information Systems:** *If the VAX network goes down, OK, we'll fix it. If the email network goes down, it's an emergency.* [LED.6.56]

> **Controller:** *We don't want to put much time or effort into the old system, because we'll be migrating to the AS/400 ManMan eventually...I spend most of my time on accounting issues. I don't want to deal with MIS now. Until the new guy comes, we'll just get by.* [SAP.4.8]

'Assessing the system' also included the work of assessing the political agenda of the information systems department. According to their accounts, it was not above the information systems group to use the MRP2 system for their own political gain:

> **Information Systems:** [The former MIS director] was in charge 5 years ago. *From what I've heard, he doesn't sound like a nice guy. He got revenge on folks. Sometimes, he deliberately didn't give people everything they needed.* [LED.6.47]

On an interpersonal level, the trust people had in the system was affected by personal relationships with the information systems workers. Part of the work of establishing trustworthiness was the work involved in building a good relationship with information systems workers. This meant coping with occasionally uncooperative or even bizarre behavior from the information systems workers. In this example, an information systems worker took delight in pressing just the right "buttons" to drive a material manager "crazy":

> **Information Systems:** *He was up here, all right.* He screamed at us, telling us how fed up he was and how you deserved to have all our support. I told him it was just a matter of creating some files and things, but he was going *berserk.* [Controller's first name] finally had to stop him and say, [material manager's first name], *the meeting's at three, OK?* At the meeting, he *chewed on us for another thirty minutes.* God. At one point, I said to him, [material manager's first name], we're doing the very best we can. He says, *hey, we need this for ISO.* And I said jokingly to him, I mean, *I know which of his buttons to push,* I said, well [material manager's first name], if we don't get ISO, we don't get ISO. *And he went crazy.* [LED.301.14]

In this third example of the kinds of trustworthiness people associate with MRP2, we see people working to assess the trustworthiness of the system itself. Part of assessing trustworthiness is understanding how the system works technically, but technical knowledge is not enough. According to their accounts, they also must evaluate the information systems workers: their capabilities, priorities, and political interests. People's assessment of the information systems group affects their use of MRP2.

Like work/benefit imbalance, trust is a meaning that people at FLEXCO use to describe their behavior when using the MRP2 system. In this section, we have seen how FLEXCO workers engage in what they define as investigation work to assess the trustworthiness of the MRP2 system, and how this trustworthiness work can be categorized into at least three types: determining accuracy, working on faith, and assessing the system.

6.3 Evaluation: How Are Others Performing, and Am I Being Judged Fairly?

A third set of meanings that guide people's use of MRP2 centers around evaluation. People's uses of parts of the full MRP2 model, according to their accounts, are shaped by their desire to evaluate how well other people and activities are performing. At the same time, people's uses of MRP2 are affected by their beliefs about how fairly the system evaluates their own behavior. In this section, I present the distinctions people at FLEXCO make between different kinds of evaluations they use through MRP2. They realize that, because their evaluation of others is only a partial view, there is always a question of what information should have more "visibility", or prominence. People also see themselves as being evaluated through MRP2 use, and their beliefs about how reasonably they are being judged play a role in their judgments about parts of the full MRP2 model.

People understand their use of MRP2 as evaluating how well other people and activities are performing. This work is called "tracking" and "checking":

> **Warehouse Supervisor:** We can track quantities by every part number issued. We can check the amount of dollars spent on this work order. [LLA.1.35]

A common way of understanding evaluation through MRP2 use is to compare "performance" to "standards" built into the system. Comparing current status to a built-in model is such a widespread way of thinking about MRP2 use that it is considered obvious. As just one example, most of the daily assembly line meeting between buyer/planners, manufacturing supervisors, and material coordinators consists of comparing "performance" to "standards":

> **Production Supervisor:** The line is 217 ahead right now. We can stop there.

> **Manufacturing Manager:** It looks good compared to labor standards...There's a slight thing on line 3 (looking at the line lead daily checksheet). 5.8%. Keep an eye on that. I notice that absenteeism on the main line is running a little high as well. What is it? Are we getting these people involved? [TAG.1.9]

Throughout FLEXCO, comparing "performance" to "standards" is how people interpret MRP2 use:

> **Production Supervisor:** These reports keep track of manpower, thruput, and quality. We watch very carefully the time standards, which are built in to the report. [ARAC.1.14]

> **Accountant:** I spend most of my time doing actual cost analysis. I'm always comparing the costs to standards, looking at the quotes. [HOJ.5.37]

The difference between "performance" and "standards" is known as "variance". Looking at the "variance" is a common way of understanding MRP2 use:

> **Production Supervisor:** This monthly report we use to *explain variance* from the schedule and the production standards. *I make a report showing the four products, show how they are different from the standards.* [NEH.1.70]

> **Warehouse Supervisor:** *Sheila does a forecast report, every week for the month. She plugs in the actuals, and compares how accurate shipping is to forecast.* [RCM.2.62]

The "standards" in the MRP2 model are used for evaluating other activities. Given that it is often clear which people are responsible for an activity, the model is also used to evaluate other people. In certain cases, the people being evaluated are modeled explicitly. For instance, these supervisors account for the use of personally-identifiable information on paper tags by the need to evaluate specific individuals:

> **Warehouse Supervisor:** The green labels? They just identify the part. So, if there's a problem, they know who to go to, and where to go, what shift. If there's a problem like the wrong part number on a bag, *we can see Trang on first shift is the one who screwed up.* [RCM.5.101]

> **Production Supervisor:** *With ISO and all the labeling*, you can see the labels out here. We can *track data by operator and by shift.* The line lead prints them out, each label. *If I take the label inside, it's only there for one shift.* That's all I need. *I can go back to the book.* [NEH.1.188]

Though their descriptions of evaluating others through MRP2 often sound authoritative, there is a recognition in their accounts that the information they use provides only a partial picture of others' performance, and that different means of evaluation are possible. Employees at FLEXCO acknowledge that people evaluate situations differently, and that they have choices about how they evaluate others. These examples recognize the different ways activities can be evaluated:

> **Buyer/Planner:** Supervisors, they *want to play what if.* They want to make decisions about head counts. They want to look at shutdowns, overtime. Engineering want to look at the fixed schedule too. They want a *rough idea of the schedule when they design.* [RAM.2.31]

> **Production Supervisor:** Quality, but not only quality. *I worry about shaving the minutes too.* I have to worry about that. [PB.1.136]

People using MRP2 make distinctions between activities they can evaluate effectively, and activities they cannot evaluate as well. In this example, a materials manager describes how he can better evaluate inventory performance on one product line versus another:

> **Materials Manager:** We have a *better handle on the computer side. Each commodity manager knows the dollars from last year, and probably knows the dollars next year. We don't have as good a handle on the auto side.* [SAC.1.63]

The uses of MRP2 information that are defined as providing a poor evaluation are part of the "black hole" (the same term used to define a lack of trust in the 'accuracy' of the system):

> **Material Coordinator:** *That's a black hole for a coordinator, or a buyer/planner, in terms of what's over there, and what's in the queue. The auto buyer/planners should be able to know if there's parts off of the floor.* [PRAC.12.143]

> **Accountant:** We used to have this program called R/FLEX running. It was there to track WIP, *so it wouldn't be a black hole.* [HOJ.3.13]

People explain their creation of new information resources away from the MRP2 model as attempts to improve their ability to evaluate other activities. In this example, providing a better view of WIP tracking is the explanation for why a set of customized reports, rather than the MRP2 system itself, is used for WIP tracking:

> **Accountant:** But the perpetual WIP tracking is *at a standstill.* We created our own using Xentis. The warehouse uses it for WIP tracking. They already have it - it gives a *little bird's eye view* of what's happening. [HOJ.1.20]

These accounts show how people see their use of MRP2 as evaluating other activities and people. If people recognize, however, that MRP2 use provides only a partial view of activities, what kinds of visibility do people prefer? How do people explain what gets visibility through MRP2 use? I will briefly mention three criteria people use for explaining what should have visibility: the 'simple and straightforward', the activities people are worried or 'nervous' about, and new views in response to past crises.

Particularly on the factory floor, employees say they prefer 'simple and straightforward' kinds of information visibility. 'Simple and straightforward' means the information is understandable and locally controlled. 'Simple and straightforward' information lets factory floor workers evaluate important activities in a way that matches their own work needs. The reports that provide visibility should be 'simple'. The information that allows floor workers to evaluate whether the right parts are on the assembly line should be 'simple' (three color-coded tags), rather than an arbitrary eight digit part number:

> **Production Supervisor:** *And the scrap report, I use this one. You can track it. This form ends up in quality. If it's simple scrap, we can do it here. If it's complicated, like a return, then it has to go to quality.* [NEH.1.112]

> **Production Supervisor:** For the flex lines, *we color coded* the labels that accompany the parts bins. The operators check for the right parts. *They don't know the part numbers, they know the descriptions* which are on these labels. *It saves me from having to baby sit on the line. If I see pink or yellow when we should be running green today, I know something's wrong.* [NEH.1.218]

Activities that people are particularly interested in at the moment, or "nervous" about, are seen as having more visibility. People using MRP2 make distinctions between activities that are "hot" or "cold", and that people are "nervous" about or "confident" about. What gets the most visibility can be a "political" question, or temporary agreement, rather than a matter of which activity has the highest revenue:

> **Buyer/Planner:** What's most visible isn't necessarily the same thing as high dollar. *It's political.* Some products are real hot, get all the attention. The [product line A] people, the high volume keyboards. [PB.1.104]

Recent events, such as a visit from an important customer, or even a comment from an important manager, can shift the common understanding of what people are "nervous" about:

> **Material Coordinator:** *I don't want my line going down. This one's on everyone's mind. Everyone's nervous about this one. It's new.* [The customer] *was just down here yesterday.* The projections say they're going to be 400 short, *but I should check on that too.* [PRAC.10.16]

MRP2 use is affected by people's evaluation of what should have visibility. In this example, a kind of MRP2 information normally considered an important evaluation tool (the amount of purchases late in arriving, or "past dues") is being "ignored" because of a "political" disagreement between the buyer/planners and the materials managers. The materials managers had decided not to replace an assistant for the buyer/planners, who had left for another job. This assistant used to help buyer/planners urge suppliers to send their shipments in on time, and his departure has created more work for the buyer/planners:

> **Buyer/Planner A:** Steve, one of our coordinators, left a couple months ago and hasn't been replaced. Since he left, our past dues have shot way up, from 2-4% to 15-20%...Actually, Betty's been *playing the bad cop* on this one... (we go into her cubicle) Whatever happened with the past dues problem? Do they see it as a problem?
>
> **Buyer/Planner B:** No. *It's a political thing.* We, in our department, are accusing another department of not doing their job. I really don't think they recognize it as an issue. [Can you show them any numbers?] Actually, we get these weekly past due percentage reports. I've thrown most of mine away, but I guess Carmen has hers. I tried just telling them, but they won't accept that. *They won't accept that it's a problem.* [PB.1.27]

A materials manager responds to this complaint by using his own criteria for what he is "nervous" about. As long as he does not see "lines down" and people "screaming", he evaluates the situation as acceptable:

> **Materials Manager:** *Well, I can see their complaint. Past dues may be up. But why? They're not up for all. Do we have to call all our suppliers to get them to do what they're supposed to do? Then maybe we shouldn't be doing business with them. I don't see the lines going down. I don't see anybody screaming.* [APS.16.68]

Employees at FLEXCO also explain what gets visibility through MRP2 use as responses to past crises. Because something terrible happened in the past, according to these accounts, a new kind of visibility through the MRP2 system is created to ensure the same problem will never happen again. In this example, a new labeling system was made to supplement the MRP2 part delivery reports:

> **Production Supervisor:** At the beginning of each shift, the operators go over this checksheet, to make sure everything's OK. We track the parts for 3 months, *every component. We had a very costly mistake last year. The material handler put some stock in the wrong container*, and we had almost a whole shift's worth of boards with the wrong part. Now they have to *compare when they put in on the reel. The sheet tells them where to put it.* [NEH.1.164]

In another example, a new WIP tracking project (separate from the existing MRP2 system) is explained as a response to an accounting error on printed circuit board product that resulted in a three hundred thousand dollar discrepancy:

> **Accountant:** *There was only one time when we had a big shrink, a 300 thousand dollar shrink. It was back when SMT first started. It was a lot cheaper to do it here,* but for a while we kept issuing *outside PCBs*. For every mouse, *we issued 3 dollars and we relieved 50 cents.* When you're doing 200 thousand mice a month, that quickly becomes a *huge* discrepancy. *Tom had to go in and tell George why 300 thousand had disappeared. That episode sort of started the whole perpetual WIP project.* [HOJ.3.68]

A preference for the 'simple and straightforward', attention to "hot" activities, and responses to past crises are examples of how people explain what gets visibility. Evaluation through MRP2 information is seen as a choice between different kinds of visibility, using separate kinds of information, but it can also be seen as using the same information in different ways. In this example, electronic orders (or "EDI") are entered in the MRP2 system with a dollar price. Due to a technical glitch, the dollar prices are disappearing. This is not important to the accountants, because they are not using the electronic prices for billing the suppliers. However, the shipping warehouse has been using the dollar prices as a way of evaluating which shipments are the most important to get out on time. Unlike the accountants, their visibility is degraded by a lack of electronic price information:

> **Information Systems:** The EDI system, when an order comes in, it should have the prices. Normally, they put the prices in the master file, but the prices are disappearing. *The dollars aren't important to* [the controller]. He's not billing through there anyway. But in shipping, *the shipping reports use dollars as a way to show what's important.* It messes them up to see the unit price at zero. [ERG.3.15]

MRP2 uses are explained as a desire to evaluate others. At the same time, the people using MRP2 recognize that they too are being evaluated through the MRP2 system. FLEXCO employees are aware of how they are being evaluated through the same system they use for their daily work:

> **Buyer/Planner:** The forecast is on the file server. They'll compare it to actual shipped dollars by month. *We're highly measured on inventory turns and product line inventory, in dollars and turns.* [RAM.2.117]

People being evaluated through MRP2 information make distinctions between "straightforward", sensible evaluation and unjustified evaluation. In these two examples, production supervisors tell why they feel confident about being evaluated fairly:

> **Production Supervisor:** [My supervisor] evaluates me by looking at safety, minutes per board, quality, scrap. *If there's a problem, how do I contribute? The evaluation is pretty much straightforward.* He looks at *all the costs real hard*, suppliers, that kind of thing. [ARAC.1.76]

> **Production Supervisor:** *My boss knows what I do. He'll go wherever he needs to and fight our battles. They know we're not on our duffs down here.* [NEH.1.215]

Evaluation through MRP2 may be seen as fair, or as overly harsh. A warehouse supervisor describes his impression of how he was evaluated through the system. He explained how being defined as "overhead" by his bosses led them to overemphasize factors such as "cost reduction":

> **Warehouse Supervisor:** Yeah, it's a tough life, right? *We're overhead, you know. If we don't reduce costs, forget it.* [RCM.2.119]

While people at FLEXCO know they are being evaluated, they do not always see MRP2 use as creating more intense monitoring. At times, they still interpret their situation as not being evaluated enough—"no one cares" about what they are doing:

> **Warehouse Supervisor:** *I'm doing the best I can with limited resources...But I don't know if anyone gives a shit about what I'm doing.* [RCM.1.170]

The distinction between 'reasonable' and 'unreasonable' evaluation (or legitimate and illegitimate) is used to describe how others use the MRP2 system to evaluate their work. Groups try to impose, through MRP2 use, what they see as 'reasonable' evaluation on others. In this example, a buyer/planner explains why she wants to impose a more elaborate evaluation scheme on work-in-process inventory trac .ing. She wants to create a more 'reasonable' evaluation:

> **Buyer/Planner:** In WIP, once it goes through, *we'd like the supplier to take the ding*. They *always looked much better* than they should. [RAM.2.130]

In another example, a materials manager explains that a 'reasonable' evaluation of the buyer/planners requires a lot of detailed information from the MRP2 system:

> **Materials Manager:** We've always had standard vs. last purchased

> price. That's always been here. Every month, we get the variance from the forecast. We look at everything on order. Why do we need all this? *We're decentralized. Buyer/planners have the authority to make substantial decisions. They give someone a verbal PO*, someone said it was OK. *It's too late at that point. How are you going to catch them?* Our air freight bill is running 20 to 40 thousand a month. [SAC.1.127]

Groups try to impose 'reasonable' evaluation schemes on others through MRP2 use when they believe that inappropriate behavior is likely. What they believe about other groups does not have to be grounded in past experience. In this example, an information systems employee argues for strong access controls on supplier performance information because of the threat of bribes or nepotism, even though there was no history of such abuses at FLEXCO (according to other informants):

> **Information Systems:** When you were talking about [our company] vs. supplier responsibility, there's a question of who can change it? When can it be done? Who has access? *A brother in law of someone might go in and change things to make a supplier look bad.* [Is that really a concern?] It doesn't happen often, *but there have been cases like that.* [LED.10.21]

A group's assessment of another group's need for strong evaluation influences the MRP2 uses they initiate and maintain. Discussing the same example as above, the same information systems employee shows how his assessment of buyer/planners leads him to believe that stronger systems controls are necessary. Allowing the buyer/planners to change the purchase order database directly (through "POODS") rather than through the official change processing program ("PODR") would be less 'reasonable', and less "official", even if he recognizes that it is more practical:

> **Information Systems:** *They don't have any discipline now. What'll keep them from changing those dates to whatever they want?* [Well, so what? They're entering the dates in now. They could change it now. Besides, why would they want to?] *They could change all the data.* Who knows why they would do it. *Some vendor promises them a boat or something. Just from an integrity standpoint,* it's the right thing to do. Not that they'd ever do it. If they would use PODR it would be *more official.*

> [Then, why don't you prevent them from changing POODS directly? Why not make them go through PODR?] *Dude, we tried that before.We tried taking away their passwords to POODS. They blew up, dude! They screamed! They said, we can't do our jobs.* [LED.22.9]

As much as groups try to impose 'reasonable' evaluation on others through MRP2 use, employees at FLEXCO recognize that evaluation requires cooperation from the people being evaluated. As much as a group might want to impose an evaluation scheme, the group being evaluated sees the possibility of resistance if they consider it too 'unreasonable'. The buyer/planners describe what would happen if others tried to evaluate them too strictly by the number of on-time deliveries from suppliers:

> **Buyer/Planner A:** *They did rate us on that at one time.* Doesn't really work, though. *If you want me to concentrate on that, fine, I will. Even if the line goes down.*
>
> **Buyer/Planner B:** It's not a good number, because we could make it look good by scheduling everything way out. Nothing would be late. But the line would come crashing down.
>
> **Buyer/Planner A:** *You can always play with the numbers.* [PB.1.162]

In another example, the buyer/planners describe how they sometimes bypass the formal procedures when the evaluation was seen as 'unreasonable':

> **Buyer/Planner:** Sometimes we *haven't been that good about getting signatures.* Anything over 5 thousand dollars requires a signature. *The signature was bypassed sometimes. The buyer/planner knows the most about the situation. Why have someone who knows less about it approve it? It's kind of insulting.* [RAM.2.211]

While groups do call for the evaluation of others through MRP2 use, they recognize that information should not always be tied to strict evaluation. If people are too fearful of being evaluated, or if they feel too "humiliated", evaluation can lead to problems:

Production Supervisor: They are most effective when they *spot trends visually, and when they feel good about themselves.* If they see a problem, they have to *let us know right away.* We can't have them *fear that they will be held responsible. I'm trying to make their jobs as easy for them as possible*, that's how I want them to see it. [ARAC.1.89]

Materials Manager: You're supposed to zoom in on the root causes of problems, and reduce turnaround, while at the same time you have to trust the employees. *Don't humiliate them.* [SAC.2.106]

Production Supervisor: Now, *we put numbers on every reel* of parts. See the before and after picture up on the wall? When it comes to quality, *it's less expensive to do it up front. You can preach at them,* but it's better *to put that chart in front of them. It's more effective* [NEH.1.175]

Even if MRP2 information is considered a 'reasonable' way to evaluate another group, the high cost of evaluation can make it impractical. In this example, an accountant interprets the failure of a 'reasonable' evaluation scheme through MRP2 as having too high a cost:

Accountant: *We used to track labor for each work order. We needed 2 full time payroll people to do this. The manager* who got that report *would say wow, that's nice, but then he'd throw it away. Now we're down to one and a half people. We just use department payroll tracking,* which shows the hours by department only. *The managers are still happy. It approximately tells us what's going on.* [HOJ.3.152]

Fine-grained evaluation, with many different categories, requires more time and resources to maintain. Keeping track of how well suppliers meet their delivery dates is considered a 'reasonable' evaluation, but maintaining the information requires work. It is especially difficult when the deliveries are changing daily:

Materials Manager: We don't have a complete reporting system for all of this. For the delivery, we don't have a place to add in whether it's an FLEXCO charge or a supplier charge. We always assume it's a supplier responsibility. [GMS.1.14]

Materials Manager: *We can't track that, because daily delivery information is not input into the system. Daily delivery performance is not*

> *entered into the system...You know, performance just isn't tracked. There's no PO for each incoming, so there's no way to match that. We don't issue off a PO and measure performance...We're not getting the follow-up. Why is it past due? Not just because of this. You don't issue a PO and measure performance. You have weekly deliveries coming off a variable schedule. Maybe suppliers should be gigged for daily delivery. I don't have all the answers. There are still philosophical issues.* [APS.16.19]

In other cases, the types of evaluation that normally take place through MRP2 use are suspended through mutual agreement. In this example, the buyer/planners explain why they were not punished for having such low production amounts in December. As long as important people know why "the numbers" are off, evaluation through the MRP2 system is adjusted accordingly:

> **Buyer/Planner:** It wasn't really as big of a deal as you might think. We made up those numbers again in the next quarter. [The customer] *was just playing a numbers game.* They always do this around March and December. They estimate the end of the year boom, then for some reason they want to reduce their inventory. We just ran through the month and kept it in truck air. They even paid for the holding costs...We have to do this. And it didn't really hurt us. [But your numbers looked bad for a quarter. Did that affect you?] No, because they knew what was going on, and we made it up the next quarter. [PB.1.11]

The question of evaluation—am I being judged fairly?—is complicated by the perception that groups disagree over how to 'reasonably' evaluate activities. This is sometimes described as having "subjective" criteria for creating specific kinds of MRP2 information. One example of disagreement at FLEXCO was over how to evaluate supplier performance. Different buyer/planners were seen as disagreeing over how to evaluate and choose different suppliers:

> **Buyer/Planner:** [How do you evaluate your suppliers?] Right now, *it's totally subjective. A supplier that is bad for me might be great for someone else. Or a supplier might bump off some of the other ones if it's high volume or high dollar. They want the good stuff, but they don't want to do the bad stuff. If we commit to them, they have to commit to us. They have*

to do both. [RAM.3.60]

The design engineers were seen as having their own supplier preferences. In this case, a buyer/planner describes a strategy to get design engineers to agree on a common evaluation scheme through MRP2:

> **Quality Engineer:** *The suppliers that give the little technical presentations, they get the calls from design engineering. You can't force the design engineer. What's in it for me? Why should I use this supplier?*
>
> **Buyer/Planner:** At my old company, *having a rating system really minimized the back door selling. I made sure, and it took a while, to get engineering buy-in on the rating system. Engineers got all the ratings.* [GMS.2.32]

Fundamentally, however, groups can disagree over 'reasonable' evaluation criteria. The same supplier that delivers on-time may not have the advanced design skill, or the same manufacturing quality:

> **Buyer/Planner:** *I feel that* [Supplier X] *has the design skill, but they can't meet the delivery schedule.* [Supplier Y], *after the mess we had, I don't want to work with them anymore.*
>
> **Quality Engineer:** *You know the situation the engineers have put them in.*
>
> **Buyer/Planner:** *I know...Engineering likes* [Supplier Z]. *But their delivery is bad.*
>
> **Quality Engineer:** *What program is that? Oh, it's too early to tell if they're a quality supplier...Changes are going down. People are looking for scapegoats, and suppliers are easy scapegoats...I wouldn't put much weight on those opinions...* [GMS.11.30]

Another example of disagreement over 'reasonable' evaluation comes from collecting assembly line performance information through MRP2. The material coordinators interpreted the failure of a project to collect performance information through MRP2 as manufacturing's "fear" of having their "real" performance made public. At the same time, there was disagreement between groups over the definition of key concepts such as "downtime" and "defects" that would be used to create the line performance information:

> **Material Coordinator:** The problem was, *I could not get any area to agree with any other areas about what downtime was exactly. The program manager over there, if they didn't have a screw, then it was clear to them. The whole thing got me into red tape, and political intrigue, even though no one looked at the data to see what was there...Me and* [the former MIS director] *were interested* in using the system to track this. *We couldn't get production to buy in. They were afraid of it.* [PRAC.12.84]

The material coordinator explains the failure of this project by appealing to his view of manufacturing as "afraid":

> **Material Coordinator:** *We were going to pilot it. But there was a big huff, and it blew up when the program managers heard. We were also going to use it for actual production numbers, what they built, and what didn't make it into shipping. To give us a more accurate picture of minutes per board. Why on this day it would be different than this day. For the program managers, the information is already being generated. From our point of view, they could be manipulated to look good for management. Production supervisors could change the numbers. It still is a problem...*
>
> [Why would production be afraid of more accurate production numbers?] They're not making it up as much as *bending the truth. But it gets very serious. Some like to keep a fat headcount.* But if they know someone is going to be away, *they need to redelegate or come up with some other arrangements...The program manager tries to lower headcount, and reduce the minutes per board. The computer would have given us accurate numbers, and limited the gray areas. They're afraid of the actuals being distributed all over, to* [FLEXCO headquarters], *even Japan. That was a huge brouhaha.* [PRAC.12.98]

Collecting information on line performance, however, requires a common definition of successful and unsuccessful operations—what is a defect, and what is a good part? But even defining defects is seen as "subjective" by a quality engineer:

> **Quality Engineer:** [Is it usually pretty clear what's a defect and what isn't?] *No, there's a lot of gray. One engineer collected all the defects,*

> *classified them, and took color photos. We published these books with all the defects in them. It made it all a little easier. But as people, customers, and products change,* we couldn't keep the book updated. *It's a thankless job for quality engineers to match requirements. Generally, you can get an agreement on requirements. But it's such a subjective topic. I wish it weren't.* [NAM.2.122]

In this section, I have shown how MRP2 use is interpreted as evaluation—trying to evaluate others, and being evaluated yourself. The people using MRP2 make subtle, complex distinctions about the legitimacy, practicality, and importance of evaluations through the MRP2 system. These perceptions guide their use of parts of the full MRP2 model.

6.4 The Meaning of MRP2 Use: From Obedience to Assessment

The results of Study 3 show, I argue, that MRP2 use is interpreted at FLEXCO as a problem of assessing whether MRP2 will help people get their work done. Using MRP2 is not interpreted as a problem of whether to obey, or disobey, the system. To phrase this point differently, people's use of MRP2 depends on their answers to the following questions:

- Is this useful for my work? Does the benefit I receive outweigh the work I must do?
- What's real here? How much work do I have to do to determine how much I trust this information?
- How are others performing, and I being judged fairly?

From their accounts, it appears that people spend a lot of time and energy answering these questions. They have to, because they do not already know the answers. The answer they find—the meanings they assign to different uses of MRP2—guide how they use parts of the full MRP2 model. The questions they do *not* spend their time answering are the questions suggested by the traditional interpretations of MRP2 problems:

- Should I obey the system?
- Should I do what's right for the organization as a whole, or for myself?

Whether to obey or not obey a formal system clearly in the interests of the whole organization is not the way these people look at MRP2 use, because the question of what works and what doesn't cannot be assumed. It has to be determined, given what a person can find out about the current situation, the history of MRP2 use, the commitments in force between groups, and people's priorities in a busy world. It cannot be assumed that others will do the work it takes to maintain MRP2 information the way you need it, or that MRP2 information can be depended on as a stable, regular account of what is happening, or that MRP2 information is used in reasonable ways.

Study 1 (reported in Chapter 4) opened the possibility that people saw their own use of MRP2 not as obedience, but as commitments, protection, incentives, and as a balance between discipline and flexibility. Study 3 confirms the existence of these meanings in more detail, but also breaks down and recombines these meanings into three distinct categories: work/benefit imbalance, trust, and evaluation. The contradictions seen in the Study 1 accounts between completely formal and completely flexible systems, between incentive and reality, and between accurate and meaningless standards have not been explained away by Study 3. They cannot be. But study 3 does show the meanings that people at one company use to make sense of these tensions in practice. We now have some knowledge of the meanings people use at work to reconcile the conflicting uses of MRP2.

Study 3 tells us that people's interpretations of work/benefit imbalance, trust, and the legitimacy of evaluation shape how they use computer systems such as MRP2, which embed an elaborate set of organizational rules. In these studies of how parts of the full MRP2 model are used in different ways, and the meanings people have developed to reconcile conflicting uses, we have strayed a seemingly long distance away from the traditional concerns of computer scientists and information systems designers. How do these results help us understand the design and implementation choices we have when designing organizational rules into computer systems? What implications do computerized organizational rule use have for the technical computer disciplines? These are the topics of Chapters 7 and 8.

Chapter 7
Computer Systems Use as an Organizational Modeling Process

Studies 1, 2, and 3 suggest a new explanation for the problems manufacturing companies have using parts of the full MRP2 model: modeling organizations is difficult. Contrary to the unified model of the organization assumed by the full MRP2 model, MRP2 use in practice leads to partial contradictions between different uses, and forces the people working with MRP2 to create a rich set of dynamically changing interpretations to understand when parts of the full MRP2 model are useful for their purposes.

In this chapter, I argue that my research results on MRP2 use are applicable to the more general problem of how to understand the use of Organizational Rule-Based Information Systems (ORBIS), first mentioned in Chapter 1. To relate my specific findings about MRP2 use to the general problem of ORBIS use, I present a new theory of ORBIS use as an organizational modeling process. According to this theory, organizational sociology concepts can be used to predict when parts of an elaborate set of computerized organizational rules will not be used: when the computerized organizational rules coordinate activities which, according to organizational sociology concepts, have important differences. Further, this theory argues that people will cope with the partially contradictory uses of ORBIS by forming three classes of interpretive judgments: judgments about work/benefit imbalance, trustworthiness, and the legitimacy of evaluation of specific ORBIS uses. At the end of this chapter, I compare this theory to other conceptual work in information systems, and relate this work to research on the relationship between human action, social structure, and technology in social theory.

7.1 Explaining Partial MRP2 Use: The Problem of ORBIS

As discussed in Chapter 2, explanations in the information systems/manufacturing research literature on MRP2 use (e.g., Cooper and Zmud, 1990; Roberts and Barrar, 1992; Sum and Yang, 1993) cannot account very well for the larger pattern of MRP2 use seen in the literature: widespread use of a limited subset of MRP2 functionality. Through a series of in-depth studies, this dissertation work offers a new explanation of failures to use the full MRP2 model. The results of Study 2 are consistent with the claim that when the organizational modeling assumptions of MRP2 are used to support organizational activities characterized by important differences (as suggested by organizational sociology theory), those parts of the full MRP2 model are less likely to be used. The three conceptual differences between activities used in Study 2—differences in technical uncertainty, outside legitimacy demands, and disagreement between the groups dominating the activities over legitimate uses of MRP2 information—were all important for explaining failures to use the full MRP2 model in the FLEXCO case. Further, the results of Study 3 are consistent with the claim that people using elaborate organizational models, such as MRP2, must maintain creative, interpretive judgments of how suited the MRP2 system is for their perceived needs at any point in time.

MRP2, and manufacturing information systems in general, are important to study in their own right. Manufacturing still plays a predominant role in the lives of over 20% of the American work force, and is key to international economic performance. However, MRP2 shares the difficulty of embedding organizational rules with many other kinds of computer systems. Because the problem of Organizational Rule-Based Information Systems is central to explaining what parts of the full MRP2 model are used, I argue that what we have learned about MRP2 use should be applicable to the use of other computer systems that embed organizational rules.

7.2 A Theory of ORBIS: An Organizational Modeling Process

In this section, I present a partial theory of Organizational Rule-Based Information System (ORBIS) use. This theory, which views the use of ORBIS as an organizational modeling process, attempts to generalize from the MRP2 example. The results from Study 2, about what parts of elaborate, computerized organizational models are less likely to be used, and the results from Study 3, about how people make interpretive judgments about the use of parts of elaborate, computerized organizational models, are combined to make a theoretical argument about where ORBIS use problems are likely to occur, and how people cope with them.

The theory of ORBIS use as an organizational modeling process can be divided in three parts:

1) The simplifying assumptions in a computerized organizational model do not support all activities equally well.

2) If part of a set of computerized organizational modeling assumptions is used by people to support multiple organizational activities, and the activities are organizationally different (as defined by concepts in organizational sociology, including differences in

technical uncertainty, outside legitimacy demands, and the social rule systems governing information use), then that part of the ORBIS model is less likely to be used.

3) The people using computerized organizational models cope with the on-going tensions of supporting partially contradictory systems uses by forming interpretive judgments of when to participate in systems uses. These interpretive judgments include three fundamental types: work/benefit imbalance [political], trustworthiness [descriptive], and the legitimacy of evaluation [normative].

Part (1) states a fundamental assumption of this theory of ORBIS use. The organizational model in ORBIS, like any model, makes simplifying assumptions about the phenomena it tries to represent. In the full MRP2 model, for example, there are assumptions about what to include or exclude (should a model of factory capacity be included?), characteristics and types (how many different types of inventory? how many categories of purchase orders?), and necessary relationships (should the product structure information in the bills of material be used to create the purchasing schedule? the cost accounting entries?). The embedded models in an ORBIS are models of organizational behavior: how people, symbols, and material resources are categorized, moved, and transformed. The key claim is that the modeling assumptions in an ORBIS do not support all organizational activities equally well. Kent (1978) argues that even the simplest data modeling choices—even how to define a name or an address—constrain or support people's ability to take certain actions. Empirically, my research contains many examples of organizational models in MRP2 (for example, work-in-process inventory models, or models of the purchasing process) that do not support all activities equally well. Gerson and Star (1986) analyze another example in medical insurance claims, where groups had different working interests in making a medical insurance coding scheme more or less elaborate.

Part (2) of the theory identifies where problems with ORBIS use are likely to occur: where parts of the ORBIS model are used to support organizational activities that are, in important ways, different. The results of Study 2 suggest that at least three theoretical distinctions, taken from organizational sociology, are important: differences in technical uncertainty, outside legitimacy demands, and social rule systems governing information use. The strength of this theory, I argue, lies in its use of concepts that have proven themselves in organizational research as powerful explanations of rationalization and rule use. These organizational sociology concepts can be used, in theory, to identify likely places where a computerized model of organizational behavior will be difficult to use. Goodhue and associates (1992) put forward this idea theoretically, looking only at differences in technical uncertainty. This theory builds on that insight, using a broader range of organizational sociology concepts.

Part (3) of the theory adds an important interpretive angle to a theory of ORBIS use. In the on-going process of organizational rule use, problems using a full ORBIS model change over time. The people using an ORBIS create their own interpretations of the system, which they use to guide their behavior. Specifically, this theory predicts that, in the on-going process of ORBIS use, people develop three important classes of interpretations to help decide when to participate in an ORBIS use: interpretations of work/benefit imbalance, trustworthiness, and the legitimacy of how people are evaluated through the system. Study 3 describes these three classes of interpretations in the case of MRP2 use. This theory claims that these three classes of interpretations—important guides towards people's use of computerized organizational rules—will be associated with other kinds of ORBIS. The systems use process is intimately tied to the on-going practice of assigning meanings to different uses—Is this useful for my work? Can I trust this? Am I being judged fairly?

7.3 Comparing with Other Information Systems Approaches

How does this theory of ORBIS use as an organizational modeling process compare to other theoretical approaches in the computing disciplines? While no other research in computer science or information systems, to my knowledge, has claimed that modeling organizations poses a distinct, and more difficult, challenge (see Chapter 1.3), other concepts in "alternative" information systems research have been applied to understanding computer use in general[1]. I list a selection of these concepts in Table 7.1. This list is not an exhaustive survey. New theories are constantly being applied to the complexities of information systems use. These concepts were chosen because of their promise for describing both the organizational content of computer systems, and the organizational context in which they are used.

I claim that my theory of ORBIS use—as an organizational modeling process—offers three distinct advantages for the study of computerized organizational rules used to support multiple activities simultaneously. First, my theory provides a description of the technical content of computer systems that isolates specific technical choices, in terms of the rules used to support different activities. Second, it provides an account of ORBIS use on the basis of proven concepts from organizational sociology. Third, it provides an account of the on-going interpretive schemes that inform the use of an ORBIS. I argue that the concepts listed in Table 7.1, each developed for purposes different than my own, are compatible with aspects of my theoretical argument.

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[1]I call this information systems research "alternative" because it is an alternative to the traditional research on information systems implementation and use, which was found wanting in Chapter 2. See Walsham (1993) for a review of this traditional implementation literature.

Table 7.1: Partial List of Concepts for Describing the "Organization" in Computer Systems

Central Concept	Distinctions	References
Values	Different assumptions about organizational work and workers; social values of important groups.	(Salzman and Rosenthal, 1994) (Forsythe, 1993)
Genres of Interaction	Typified interactions with similar (computerized) form and substance (e.g., business memo, project meeting)	(Yates and Orlikowski, 1991)
Grammars of Action	Formal languages which reorganize activity to allow information capture.	(Agre, 1994)
Coordination Mechanisms	Formal processes to manage dependencies between activities.	(Malone and Crowston, 1994)
Institutions	Social organization of computing (equipment configuration, skills and roles, infrastructure).	(Kling and Iacono, 1989)
Boundary Objects	Objects with flexibility for local needs, but with a common identity across social worlds (lists, standardized forms).	(King and Star, 1990) (Henderson, 1991)
Web Models	The context of computing (people, equipment, spatial, and temporal dimensions) and its resource dependencies	(Kling, 1987)
Adaptive Structuration	Embedded social structures which enable and constrain interaction (technical capabilities + "spirit" or general intent).	(DeSanctis and Poole, 1994)
Surveillance	Types and intensity of monitoring (e.g., the "panopticon").	(Rule and Brantley, 1992) (Zuboff, 1988)
Organizational Rules	Organizational modeling assumptions, used to support different activities simultaneously.	(Allen, 1995)

The concept of values, or organizational assumptions being built into computer systems (e.g., Salzman and Rosenthal, 1994), is one that fits well within my overall argument about the organizational model built into computer systems. Concepts such as grammars of action (Agre, 1994) specify the technical content of computer systems, while concepts such as web models (Kling, 1987) and the social organization of computing (Kling and Iacono, 1989) identify the immediate context of computer systems. The concept of coordination mechanisms (Malone and Crowston, 1994) is compatible with part (2) of my theory, where differences in technical uncertainty predict contradictions in systems use. The concept of organizational surveillance (e.g., Rule and Brantley, 1992) is compatible with part (3) of my theory, where the people using an ORBIS make crucial interpretive judgments about the legitimacy of evaluation through system use. Both the concepts of adaptive structuration (DeSanctis and Poole, 1994) and genres of interaction (Yates and Orlikowski, 1991) capture aspects of the dynamic interplay between the action strategies of people, and technical features of the computer system, as does the concept of boundary objects (e.g., King and Star, 1990).

Many of these theoretical arguments, however, do not choose to take advantage of previous research on organizational rule use. Those that can, do not have a conceptualization of the role of human interpretation in organizational rules. Therefore, for my particular explanatory purposes, I argue it is worthwhile to focus attention on the organizational rules in computer systems, and to view ORBIS use as organizational modeling process.

7.4 ORBIS Use and Social Theory

In my theory of ORBIS use as an organizational modeling process, there is an emphasis on *process*. Interpretations condition certain kinds of ORBIS use, which in turn alter the interpretations. In this theory, the emphasis was on interpretations that assessed the effort required, trustworthiness, and the legitimacy of evaluation through the system. These interpretations, in turn, shaped people's willingness to use or not use the information system in particular ways.

My understanding of information use as a process has been influenced by the social theory of Giddens (1984) and his interpreters (e.g., Orlikowski and Robey, 1991). Giddens' basic insight is that social rules and resources are simultaneous a medium and an outcome of individual action. The social rules and resources provide a medium, a basic vocabulary that enables and constrains what individuals are able to do. At the same time, by using social rules and resources, individuals further perpetuate them—the social world is an outcome of individual action. The metaphor Giddens uses is natural language: the rules of grammar enable and constrain what individuals can say and still be understood by others, but the rules of grammar only exist to the extent that people use them.

In part (3) of my theory of ORBIS use, I identify three classes of interpretations as fundamental: work/benefit imbalance, trustworthiness, and the legitimacy of evaluation. Why these three? My initial answer is, because they emerged from the data analysis in Study 3. However, these three classes can be mapped on to Giddens' three analytic dimensions of structuration (Giddens, 1984). A concern with work/benefit imbalance is fundamentally about power and interests. A concern with trustworthy, useful accounts of what is happening in organizations is about communication and signification (i.e., understanding the world). A concern with evaluation legitimacy is about norms and sanctions. Similarly, these three classes can be mapped on to the three different types of social rule systems (Burns and Flam, 1987): descriptive, prescriptive, and evaluative. An argument can be made that the three classes of interpretations relate to the dimensions found in recent advances in social theory.[2]

Speculating about advanced social theory is well beyond the scope of this dissertation. But because structuration is considered the best account of social process in current information systems research, I believe structuration has to be examined critically by any theory describing the process of systems use. Can a technological system, with a separate material existence, be incorporated in this structuration process? As many observers have

[2]Mark Ackerman encouraged me to pursue this issue.

noted, and complained (e.g., Sewell, 1992), Giddens defines social structure (the social rules and resources) as having only a virtual existence. Orlikowski (1992) addressed this omission by placing technology into a separate, privileged position between individuals and the social world. Sewell (1992), however, provides a reinterpretation of the structuration idea which, I argue, deals more elegantly with this issue.

For Sewell, the social world, which is both a medium and outcome of individual action, has a simultaneous symbolic and material existence. The social world consists of symbolic systems (such as norms and meanings) which have only a virtual existence, and physical resources which have a material existence. Our symbolic systems guide how we create our material resources—symbolic systems enact physical resources. Our physical resources, our material existence is read by individuals and used to validate the existence of mutually understood symbolic systems. This approach to the structuration of actors (individuals) and resources (the social world individuals use, and are used through) is illustrated in Figure 7.2.

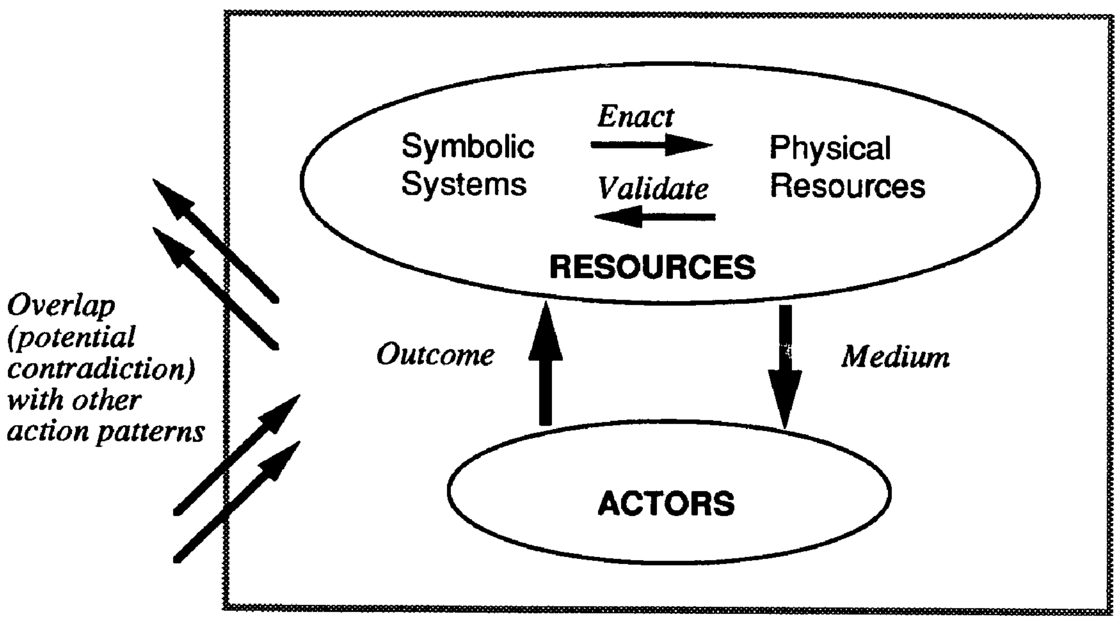

Figure 7.1: A Theory of Structuration (Symbolic and Physical)

Sewell's other contribution is his account of where change occurs in this structuration process. Changes in the social world come from 'slips' in any of the structuration processes mentioned above. A process 'slips' when the reproduction of existing social resources is not perfect. 'Slips' occur for two reasons: the unpredictability of the world, and the creative application of different social resources by an individual. 'Slips' in enactment can occur, for example, because people cannot perfectly predict if their plans for building a dam or planting a crop will come to be. A 'slip' in validation might occur when individuals creatively apply a different symbolic system to a physical resource—for instance, interpreting a dam as an 'environmental hazard' rather than a 'source of energy and flood control' or a 'symbol of human progress'.

Though my goal was not to advance this kind of social theory, I believe that computerized organizational models such as MRP2 give us an example of how these concepts could be applied. The interaction between meanings and MRP2 use can be seen as a process of a meanings enacting a physical resource (the information technology itself), and the physical resource being read to validate people's symbolic assessment of the information system. Particularly important is the notion of change, or 'slip', as people use the same social resources to support overlapping activities. The attempt to use a master production schedule as a motivation tool, for example, initiates a 'slip' that creates a partial breakdown in the reproduction of a social resource known as 'the accurate picture of reality'. Understanding the timing and nature of these slips will be crucially important for moving beyond static differences in organizational activities as an explanation of when information systems are no longer used.

In this chapter, I presented the assumptions and claims of an organizational modeling process theory of Organizational Rule-Based Information Systems (ORBIS) use. The key dilemma is that an ORBIS is used to support many different organizational activities simultaneously. Chapter 8 looks at the implications of this simple claim for the computing disciplines.

Chapter 8
The Implications of Organizational Rule-Based Information Systems

Computerized organizational models, like the written and oral models that came before them, are used to simultaneously accomplish many different things. As we have seen with the MRP2 example, a factory production schedule can be used as an accurate picture of what is happening, a motivational goal to strive for, a medium for learning about the organization, and as a basis for reward and punishment. The complexity of these multiple, partially conflicting uses makes computer systems with elaborate organizational rules (what I have called Organizational Rule-Based Information Systems, or ORBIS) particularly challenging to design and implement well.

This chapter looks at how the theory of ORBIS use as an organizational modeling process can contribute to three different research communities struggling with the design of organizational rules into computer systems. In computer science itself, I argue that my approach foregrounds the neglected issue of how systems design is a modeling process, and opens the door for organizational analysis in the systems lifecycle. In the emerging field of Computer-Supported Cooperative Work (CSCW), I argue that an emphasis on organizational rules can keep the designers of workflow and other structured groupware from repeating the same sterile debates about the "pros" and "cons" of formalization. For the field of information systems architecture, I argue that my approach gives us criteria for deciding when to link elaborate organizational models together, and when to keep them apart.

8.1 Multiple Use Systems

I would characterize systems which embed computerized organizational models, or ORBIS systems, as "multiple use" systems. Why? Because, like organizational rules, computerized organizational models are used to support multiple activities simultaneously. Saying that a computer system has multiple uses challenges a central idea of the computing disciplines—the systems approach. The systems approach assumes that the world can be modeled as systems, or "group[s] of related elements organized for a purpose." (Bullock and Trombley, 1991; 842). The idea that a computer system serves multiple purposes in practice questions the basic definition of a system as having a clear purpose (e.g., efficiency, or survival). Indirectly, it challenges the systems analysis method of first determining a single, consistent set of requirements for a computer system, then building a system that meets these requirements.

The question that remains is: what do we do? What are the implications of multiple use systems like ORBIS for building computer systems? Acknowledging the multiple uses of computerized organizational rules does not bring the whole systems analysis enterprise to a screeching halt. Certainly, there are large commonalties in the information needs of many organizational activities (or the organization would likely cease to exist). But it does tell us that the commonality of information needs—the commonality of purpose, in systems analysis terms—cannot be assumed as easily with ORBIS. The extent of the differences between organizational activities has to be determined through investigation. In the rest of this section, I look at the implications of one particular aspect of multiple use systems: tying together organizational activities through computerized organizational models.

8.2 The Implications for Computer Science

The main implication of this work for computer science is that it should take its own emphasis on modeling more seriously. The classical theorists of computer science describe the building of computer systems as a modeling process (Aho and Ullman, 1992; Wirth, 1986). Building a model requires simplification—abstracting away unnecessary details to create a computational solution. How do computer scientists know if they have made the right abstraction choices? They depend on designer experience, the experience of clients, and on measures of internal technical efficiency. But they have no conceptual measure of the appropriateness of a modeling choice for solving a real-world problem. Computer science does not have a theory of the relationship between computerized representations and action in the real world (Smith, 1991).

Making good models is a matter of making good assumptions about what is important. Walker (1994) and Smith (1991) discuss the difficulty of creating good computational models. Even when computer scientists can rely on accepted mathematical and physical models, the complexity of real-world engineering problems, such as missile detection or aircraft guidance, makes good modeling difficult, because complete modeling is impossible.

The problem of creating good computational models is even more complicated when organizational behavior is involved. In cases such as MRP2, when there is "disagreement about the meaning, interpretation, or intended use of the same or related data," the modeling dilemmas are "poorly understood and...there is not even an agreement regarding a clear definition of the problem" (Sheth and Larson, 1990; 187). What computer science should recognize is that making good organizational modeling choices depends, in part, on organizational criteria. As Norman (1991) argues:

> Computer systems intended to aid people, especially groups of people, must be built to fit the needs of the people. And there is no way that a system can work well with people, especially collaborative groups, without a deep, fundamental understanding of people and groups. Needless to say, this is not the sort of skill taught in computer science departments.

Study 2 suggests one way that organizational criteria could be used to make computer modeling decisions. Study 2 implies that one way of determining whether to technically link together sets of organizational rules is to look at the differences between organizational activities, as characterized by organizational sociology concepts. If the activities are very different along important theoretical dimensions, then designers should be more reluctant to tightly integrate those data models technically.

Using organizational concepts for technical decision-making in computer science might appear to be a radical departure, but actually is quite compatible with accepted thinking on software engineering and design. The commonly-accepted spiral model of the software process (Boehm, 1988) provides a "risk-driven" approach to systems building. Each iteration of the development "spiral" begins with a risk analysis phase, in which the builders "identify areas of uncertainty that are significant sources of project risk" (Boehm, 1988; 65). The possible strategies for reducing these risks include building technology, but can also include questionnaires, examination of other sites, further research, and other strategies. There is nothing precluding the use of organizational concepts to evaluate particular technical decisions. There is nothing preventing the use of organizational concepts to evaluate organizational risks.

Dasgupta (1991), in his discussion of design theory in computer science, further clarifies this risk-driven process by arguing that design is the progressive evolution of a set of hypotheses. In a systems design, an initial set of hypotheses about how a situation can be improved through computer support are refined, assumed, validated, and refuted until the key hypotheses are reduced to a computable form. Again, in validating or refuting the claims a design makes about what should exist in the world, there is nothing to preclude the use of organizational concepts, if a design has to make important assumptions about the organization.

Using organizational concepts to help make technical decisions would be unconventional for computer science, but I argue it is necessary when a system makes modeling assumptions about human organizations. Surprisingly, there is little in the accepted wisdom on systems design to prevent us from doing so. That does not mean it will be easy. As one commentator noted many years ago (Burck, 1965; 138):

> programming will become vastly more difficult as the machine is used more and more in solving "human" problems...if the computer is asked to solve a problem in which human motivation is important, it will have to be told exactly what that motivation is, and what to do about it and under what circumstances. That will not be easy.

8.3 The Implications for Computer-Supported Cooperative Work

For the emerging field of Computer-Supported Cooperative Work (CSCW), this research offers a rich example, and a set of theoretical tools that could help the CSCW field cope with the problem of formalization.

First, this research offers a rich example of computer-supported group work. MRP2 tightly links many different groups and activities together through a shared computing environment. This study provides a detailed look at, for example, work/benefit imbalance in CSCW, a widely accepted insight (e.g., Grudin, 1994) that is based on few examples. In addition, it opens up trustworthiness work and evaluation legitimacy as central concerns for CSCW. The participant-observer Study 3 reveals the importance of human interpretations for the on-going process of CSCW use—a subjected that has been neglected in CSCW research to date.

Perhaps more importantly, however, this research may offer a theoretical tool for coping with the debate over formalization in CSCW systems. CSCW research is based on the notion that supporting group work requires special kinds of systems capabilities beyond those needed for individual work. In other words, a CSCW system needs to have some "awareness" of group work (e.g., Mandviwalla and Olfman, 1994). One of the most obvious ways of giving a computer system "awareness" of group work is to build in a formal model of group activity. This approach is most obvious in the workflow automation applications, which create a formal model of organizational work activities. The temptation to strongly formalize work through CSCW systems has spurred a heated debate, framed as an argument either for or against formalization (e.g., Suchman, 1994; Winograd, 1994).

The debate over formalization is a dead end, I argue, and sadly neglects years of research on formalization in organizations. On one side is an argument against the oppressive nature of all categorization; on the other, an argument that formalization is just a tool that can be used for good or evil. An organizational rules approach helps show CSCW researchers how formal resource use contributes to efficient work, power consolidation, symbolic allegiance, and many other processes found in the organizational literature. An organizational rules approach would help the field evaluate how and why formal resources work in organizations, before pronouncements are made on how they should work. This approach could also explain the mechanisms and reasons behind commonly accepted CSCW design guidelines, which has progressed so far without a strong theoretical base (e.g. Grudin, 1994; Robinson, 1993).

8.4 The Implications for Information Systems Architecture

For people building information systems architectures, this research suggests organizational concepts can be used to partially decide what kind of organizational models to build. In particular, it gives information systems researchers new criteria for deciding when to link elaborate organizational models together, and when to keep them apart.

Not trying to support activities that are too different through the same information models has been suggested before. Goodhue and associates (1992) claimed that activities with different degrees of technical uncertainty would be less likely to use the same information models. In Study 2, I extended this insight by including differences in outside legitimacy demands, and differences in beliefs about legitimate behavior.

The information systems field has long had a need for concepts that would avoid excess centralization in systems. Since the earliest days of the field, a common information architecture has been seen as having a strongly centralizing influence (e.g., Mann and Williams, 1960)[1]. Recent research on information architectures suggests that large-scale

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[1]This is different from saying that computer use in general has led to a centralization of decision-making authority. There are other aspects of computing—the dispersal of computing resources, the lowering of skill barriers to programming—that have had a decentralizing influence. I am only arguing that having a common data architecture has encouraged centralization. (See George and King, 1991, for a review of

organizational modeling efforts through computing often fall apart because of over-centralization (Goodhue et al, 1988) and political conflict (Davenport et al, 1992). With both technical and ideological biases towards centralized information architectures, an organizational rules approach can be used to identify which shared architectures are most likely to experience contradictions in use, and how those contradictions will be experience by the people involved.

In this chapter, I have briefly reviewed the main implications of this research for organizational modeling in computer science, CSCW, and information systems architectures. In all these fields, an organizational rules approach lets us take advantage of a rich stream of organizational research to understand the choices we have in how to build organizational rules into computer systems. Someday, organizational concepts should become an accepted part of the toolbox for technologists building systems that support organizational activities.

centralization/decentralization research).

Chapter 9
Conclusions, Limitations, and Future Research

In this dissertation, I developed and tested a new explanation for why manufacturing organizations have problems using parts of the full MRP2 model. This research shows how the differences between organizational activities coordinated through computing, and the orientations people have towards reconciling these different uses, are central issues. In the process, I created a new way of looking at computer systems that embed organizational rules. Apparently, there is something different about modeling human organizations. I have tried to take the first steps in showing that we sometimes need organizational concepts to make good technical decisions, such as whether to tightly integrate sets of organizational models.

In the first section of this chapter, I summarize the claims made in this research project. Study 1, an interpretive study of MRP2 professional training, found that conflicts between different uses of MRP2 were the explanations given for failures to use parts of the full MRP2 model, rather than problem individuals or a lack of attention to data accuracy. Study 1 also found that MRP2 professionals create innovative meanings, such as "commitment" and "protection", to reconcile the different uses of MRP2. Study 2 found that failures to use the full MRP2 model were associated with differences between organizational activities, at one innovative manufacturer. Study 3 found people using their assessments of work/benefit imbalance, trustworthiness, and evaluation legitimacy to decide which uses of the MRP2 model to participate in. This series of studies led to a new theory of Organizational Rule-Based Information Systems (ORBIS) use as an organizational modeling process. The new theory emphasizes that the simplifying assumptions made by the organizational rules embedded in computer systems do not support all activities equally well.

Finally, I discuss the limitations of this work, and possibilities for future research. The major limitations are theoretical and practical. Theoretically, generalization can only take place at the conceptual level, so the acceptance of this work will depend on other studies challenging, breaking, and expanding my results. On the practical side, it is unclear whether abstract organizational concepts can be turned into something usable by computing professionals. Each of these limitations opens up possibilities for future research.

9.1 Summarizing the Research

Figure 9.1 summarizes the answers to the research questions first posed in chapter 3. The results of Study 1, an interpretive study of MRP2 professional training, first suggested that the differences between organizational activities linked through computing, and the orientations people have towards reconciling the different uses of MRP2, explain when parts of the full MRP2 model are used or not. While the MRP2 professionals explicitly claimed that individual behavior problems (such as a "lack of discipline") were the reason for MRP2 use problems, their stories of specific failures to use MRP2 explained problems as conflict between groups. To the MRP2 professionals, diverse goals and interests are a fact of life. While other groups are condemned for having different MRP2 use preferences, ultimately the MRP2 professionals recognize many groups as having legitimately different needs. The choice of whether to use MRP2 was not seen as a choice between individual and organizational benefit, but as an attempt to reconcile the needs of different activities.

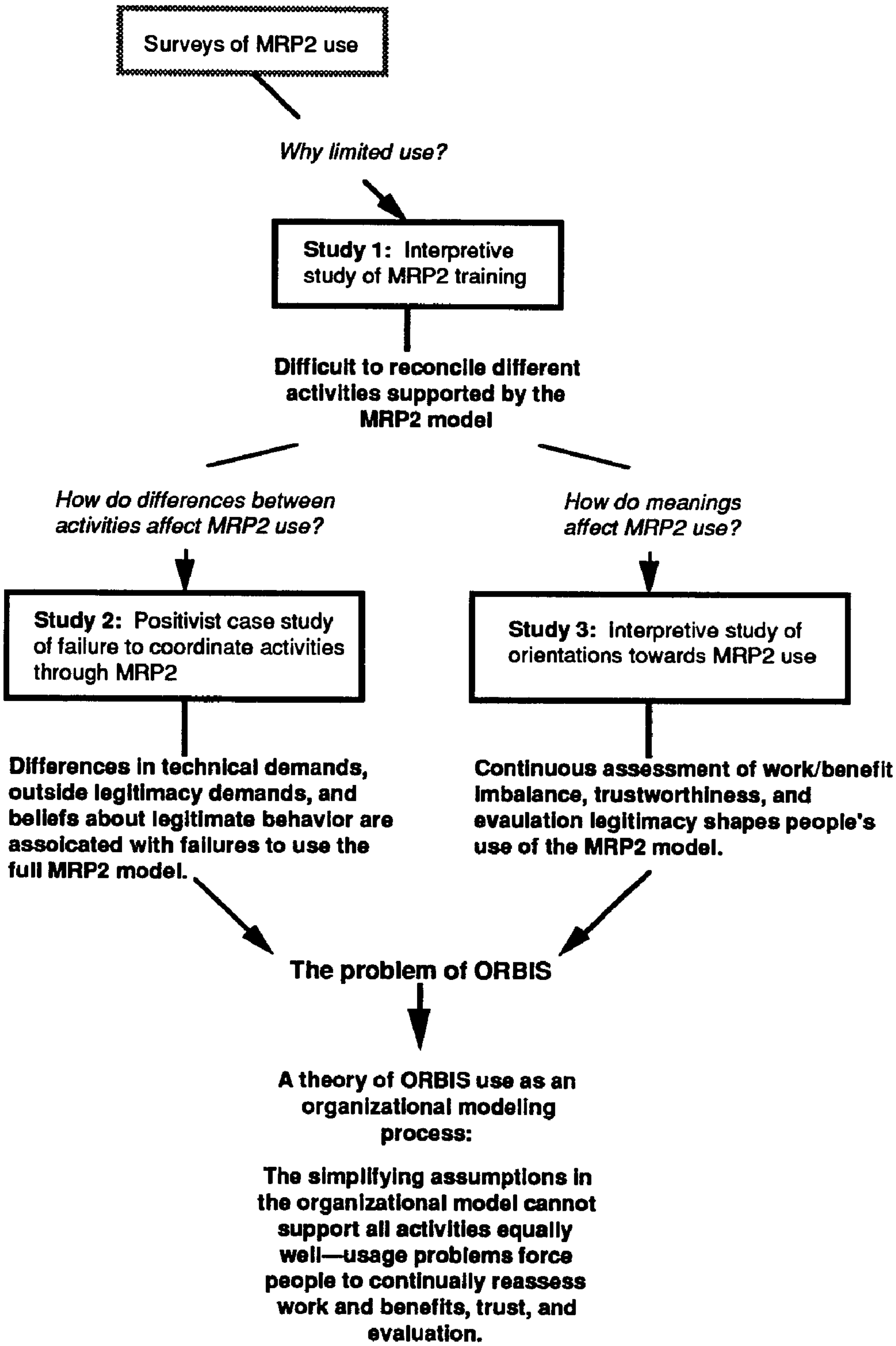

Figure 9.1: Overview of Research Project Claims

The accounts of conflict around using parts of the full MRP2 model were grouped into three types: direct clashes, indirect clashes, and incentive clashes. In these accounts, planners realize that making the MRP2 fit their work (i.e., "match reality") is difficult—they must learn when the model will work. The implicit and incentive clashes were largely between the most prominent "simulaters" (the production planners) and "simulatees" (the manufacturing workers). Despite a loss of "accuracy", planners consider it legitimate to use the master schedule as an incentive under certain conditions.

Study 1 also found that MRP2 professionals create innovative meanings to reconcile the different uses of MRP2. According to their accounts, MRP2 professionals interpret their legitimate need to work around or outside the formal MRP2 system as maintaining a reasonable balance between "discipline" and "flexibility". MRP2 use was seen as a means for making "commitments" between parties (based on "the truth" or "a lie"), but at the same time was seen as "protection" from the illegitimate demands of others, or uncertainty. As a "protection" tool, MRP2 was appealed to as an impartial view of reality, yet the MRP2 model could be filled with arbitrary values for legitimate "protection" purposes.

Study 2 used the new interpretive understanding gained from Study 1 to test a new positivist explanation of when manufacturing companies fail to use parts of the full MRP2 model. Study 2 found that failures to use parts of the full MRP2 model were associated with differences between organizational activities at one innovative manufacturer. All three differences in organizational activities suggested by concepts from organizational sociology (differences in technical uncertainty, outside legitimacy demands, and beliefs about legitimate behavior) were needed to account for all the the failures to use the full MRP2 model in the FLEXCO case. No one theory could be eliminated as having no explanatory power.

The data analysis from Study 2 suggests that differences in outside legitimacy demands tend to exist on their own—they are not associated with internal differences in beliefs about legitimate uses of MRP2 information, or technical uncertainty differences. The data analysis revealed that differences in technical uncertainty can be, but are not always, associated with differences in beliefs about legitimate behavior. It is possible (as in the relationship between scheduling and inventory activities) to legitimately recognize technical differences. But it is also possible to have more problematic relationships (such as between scheduling and manufacturing activities) where there are both technical differences and differences in beliefs about legitimate behavior.

Study 3 further revised the new interpretive understanding of how people reconcile the different, partially contradictory uses of MRP2 identified in Study 1. Study 3 found people using their assessments of work/benefit imbalance, trustworthiness, and evaluation legitimacy to decide which parts of the full MRP2 model to participate in. Because of what they interpreted as the partially conflicting needs of different work activities, people using MRP2 understood themselves as continuously assessing these issues to decide whether to participate in particular uses of the MRP2 model.

MRP2 use is seen as having chronic work/benefit imbalances in "busy" organizations with differences in "priorities". Some groups are perceived as directly benefitting from MRP2 use, and others as having to suffer through the "bureaucracy" imposed by others. People's perceptions of work/benefit imbalance shape whether they use the MRP2 model, or attempt to create their own separate information resources.

The people using MRP2 in Study 3 also interpret themselves as spending a significant amount of effort assessing the trustworthiness of MRP2 information for a particular use. Their assessment of how much they can trust the information guides whether they use parts of the full MRP2 model or not. The work they do to verify trustworthiness comes in three forms. First, people work to assess the "accuracy" of information. "Accuracy" is not an all-or-nothing property—people often have to cope with "mostly accurate" or "almost useless" information. Second, people assess whether they can 'work on faith'—whether the "commitments" entered in the system (i.e., information on hypothetical futures, such as a promised delivery date) can be relied on. Third, people assess the trustworthiness of the information system itself—not so much the technical reliability, at least in this case, but rather the abilities and agenda of the information systems group responsible for the system.

Finally, MRP2 uses were shaped by a desire to evaluate other activities, and people's beliefs about how they were being evaluated. The question of what is visible, or should be visible, through MRP2 use guided people's behavior. People's assessment of how well they could evaluate other activities, and how legitimately they were being evaluated, were resources for deciding which MRP2 uses to participate in.

This series of studies led to a new theory of Organizational Rule-Based Information Systems (ORBIS) use as an organizational modeling process. The new theory emphasizes that the simplifying assumptions made by the organizational rules embedded in computer systems do not support all activities equally well. Usage problems with computerized organizational models force people to continuously reassess the balance between work and benefits, their trust, and the legitimacy of evaluation in their information systems.

9.2 Limitations of This Research

The major limitations of this study are theoretical and practical. Theoretically, generalization can only take place at the conceptual level, so the acceptance of this work will depend on other studies challenging, breaking, and expanding these results. On the practical side, it is unclear whether abstract organizational concepts, and types of human interpretations, can be turned into something usable by computing professionals.

This research used a relatively untested research model (the framework described in Lee, 1991), and a small set of theoretical concepts from organizational sociology, to study one particular kind of information system (MRP2) primarily in one organization (FLEXCO). Each choice carries its own limitations. Studying MRP2 in one organization has its limitations, but it is now well understood how generalization in case study research takes place at the conceptual level (Yin, 1984). Further acceptance of this case will depend on other studies challenging these results. More limiting, perhaps, is the choice of MRP2 systems as a kind of computerized organizational model. MRP2 has the virtue of being in widespread use, and having a long history, but it is difficult to know how much of the peculiarities of this data architecture affect its sensitivity to organizational differences. Any attempt to apply these insights to other computer-based organizational rules must be alert to the tremendous complexity and interconnectedness of the organizational rules found in an MRP2 system.

The most severe limitation, in my opinion, is the use of a small set of theoretical concepts. Why were those theories chosen for Study 2, and not others? After a new interpretation of failures to use the full MRP2 model came out of Study 1, there was nothing dictating that the research use this particular set of concepts, beyond their role in previously explaining rationalization in organizations. The conflicts between uses of MRP2 could have been addressed through other organizational theories, of which there are many (Scott, 1992). And the concepts used—the differences between activities—only scratch the surface of what those theoretical traditions have to offer. Study 2 was only able to understand the conflicts between groups in terms of three theoretical concepts. Other ways of framing the differences between organizational activities simultaneously supported by an ORBIS remain unexplored.

The practical limitations of this work are significant. Though I claim that this research eases the path towards using organizational concepts for technical decision-making, there is no evidence in this study that using organizational concepts would be practical for computer professionals. Any practical effort to expand computer science or information systems practice in this direction is left for the future.

9.3 Future Research

While the theoretical and practical limitations of this research are an issue, they can seen by optimists as opportunities for future research.

Our understanding Organizational Rule-Based Information Systems use can progress on a conceptual level by looking at a diversity of organizational models, and by examining the process of model use with stronger theory. By comparing the MRP2-type models used by a variety of manufacturing firms, future research can identify more precisely when the use of elaborate, computerized organizational models falls apart. But in addition to calling for more research sites, there is a real opportunity for future research to study the process of organizational rule use in computers. Study 3 identified the important meanings people use to make MRP2 decisions, but says little about how those meanings change over time to encourage use or abandonment. A study of the history of model use would identify, through these and other meanings, how and why information resources become ignored, or denounced as illegitimate. Future research on the longer-term process of organizational rule use would benefit from the ideas on structuration and 'slip' presented in section 7.4.

On a practical level, the question of what computer technologists should know about organizations, and how they should know it, is still very much an open question. Collections of readings are available to expose computer technologists to organizational issues (e.g., Kling, 1995; Huff and Finholt, 1994). Computer technologists can use traditional "user involvement" strategies, or the more recent "mutual learning" techniques (e.g., Greenbaum and Kyng, 1991), to learn about the preferences of the people who will use the system. Kling and Allen (1995) argue, however, that computer technologists, with their unique awareness of technological choices and influence over the change process, need to know much more about the organizations they design for. Future research needs to look at how much more conceptual knowledge about organizations technologists can practically use, and whether this conceptual knowledge improves the design and use of computer systems.

Questions about how to think about the problem of organizational rules in computer systems will not go away any time soon. Not only are our technological capabilities for electronic organizational modeling increasing, but the trend towards purchasing more elaborate computer systems from outside vendors raises the question of whether organizations really know what kind of organization they are. The task before us is to make sure we are asking the right kinds of questions about these systems. The best way to do this, as always, is to study the history of real systems, using a rich theoretical legacy. The information workers of the future are depending on us.

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