Control in the Extended Enterprise

by

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Abstract

In recent years, manufacturing organizations have adopted distributed and decentralized manufacturing systems as a means of increasing flexibility and maintaining cost effectiveness in order to remain competitive now and in the future. Emergence of various next generation manufacturing ideas, such as lean manufacturing, agile manufacturing, the virtual organization, and world-class manufacturing reflect a major trend toward distributed and decentralized manufacturing systems. Although a number of researchers have suggested difficulties in controlling and coordinating different manufacturing activities across heterogeneous manufacturing units, there is a lack of research attention on the design of effective management control systems of these cooperative efforts. Therefore, this research examines control issues of heterogeneous manufacturing units within a framework of the extended enterprise.

Lack of research on inter-organizational control and management issues led us to build a novel framework for this study based on the widely accepted theories of intra-organizational control, such as the study of Burns and Stalker (1961) which identified two pure forms of management control -- mechanistic and organic. Based on these two models of control, we identified four types of basic interactions of the mechanistic and/or organic management control systems in an extended enterprise. Using this framework, we investigated the impact of the interactions of mechanistic and/or organic management control systems within an extended enterprise on organizational performance in both stable and dynamic environments, and on the viability of both mechanistic and organic management control systems for inter-organizational control within an extended enterprise in both stable and dynamic environments. Using a contingent approach, we employed system dynamics (SD) simulation modeling as the instrument of this research. Experimenting with SD simulation models, helped to understand the interrelationships between multiple dependent (or contingent) variables (i.e. external environmental condition, interactions of mechanistic and/or organic management control systems, and structures of extended enterprises) and independent variables (i.e. organizational performance) in compressed time and space. Statistical analyses indicated that a perceived "sound" framework of management control systems (i.e. the all organic management control systems) does not always perform better in an extended enterprise.

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Finally, to my dear friend Salim Dastagir (1959 ~ 1996), your presence taught me how to be a better person and a good researcher. Salim my friend, my research work is done.

Dedication

To my parents, Keunho and Wansun Baik,
thank you for all the support and encouragement.

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CHAPTER ONE

Introduction

1.1 Introduction

For many manufacturing organizations, the use of distributed, decentralized, and heterogeneous manufacturing systems represent alternative solutions to increase flexibility and to maintain cost effectiveness in order to remain competitive at present and in the future. Emergence of various next generation manufacturing ideas, such as lean manufacturing (Womack *et al.*, 1990), agile manufacturing (Iacocca Institute, 1991; Goldman *et al.*, 1995), the virtual organization (Davidow and Malone, 1992; Goldman *et al.*, 1995), and world-class manufacturing (Schonberger, 1996) reflect a major trend toward distributed and decentralized manufacturing systems (NGM, 1997).

Although these advanced manufacturing strategies have been developed more or less independently, they all propose a form of cooperation and coordination with different integral subunits within and beyond the traditional four walls of a single manufacturing organization, and as such they extend the traditional reach of organizations. An extended enterprise, also known as "virtual company" or "flexible manufacturing network" (Landay, 1995), "is the seamless integration of a group of companies and suppliers (industrial, educational, investment, and governmental) that collaborates to create and support a timely and cost-effective service or product" (NGM, 1997). From this point on, we refer to distributed, decentralized, and heterogeneous manufacturing systems that strive to implement the various state-of-the-art operations strategies as extended enterprises.

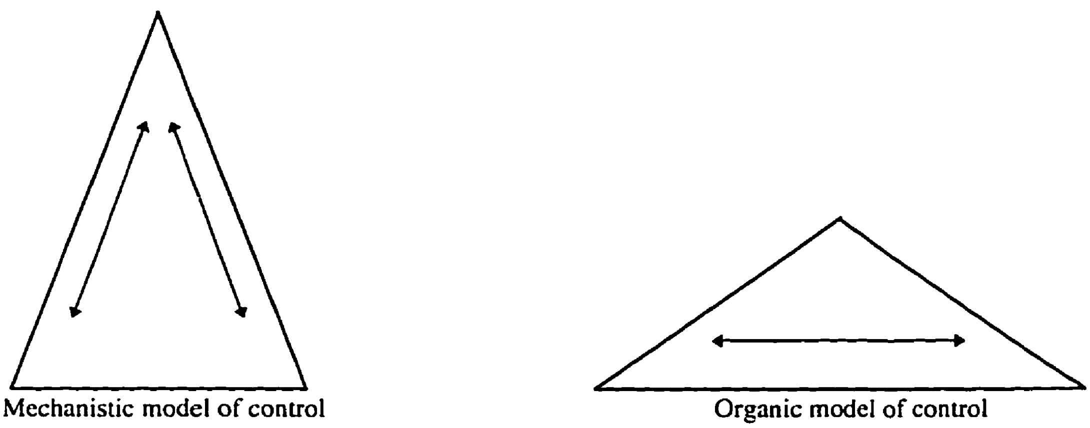
A number of researchers have suggested implementation of such cooperative manufacturing systems as the foundation of superior manufacturing performance (Hayes *et al.*, 1988; Buzacott, 1994; O'Neill and Sackett, 1994). However, controlling and coordinating different manufacturing activities across many individual heterogeneous manufacturing units has become a much more difficult and complex task (O'Neill and Sackett, 1994).

So far, most current advanced cooperative manufacturing support-related research efforts have been focused on information technology (IT) (Ching *et al.*, 1993; National Research Council, 1995). IT is a means to integrate and coordinate various basic manufacturing activities such as production, design, and business, and thus to improve manufacturing. However, as National Research Council (1995) points out, "the full potential of information technology to improve manufacturing will require addressing many non-technological matters, as well as the technical areas." Thus, this research examines one of these non-technological issues: control issues of extended enterprises arising from the integration of basic activities within and between heterogeneous manufacturing units (i.e. intra- and inter-organization(s) integration).

From a control perspective, Simons (1994) defines management control systems as "the formal, information-based routines and procedures managers use to maintain or alter patterns in organizational activities." Over the past decade, it has been discovered that traditional forms of management control systems based on the "mechanistic model" (Burns and Stalker, 1961) are inadequate to deal with the acceleration in the pace and intensity of changes firms face (Johnson and Kaplan, 1987; Kaplan, 1990; Johnson, 1992, 1995; Egol *et al.*, 1995). The mechanistic model of control --also known as the pure cybernetic model of control (Hofstede, 1978)-- is characterized by its "vertical processes" (Galbraith, 1995), such as hierarchic structure of control, centralized decision making, vertical information flow, and authoritarianism. The model is known to be effective in relatively stable environments (Burns and Stalker, 1961).

However, a number of studies have suggested that a viable alternative for organizations operating in dynamic environments is to adopt the organic model of control (Burns and Stalker, 1961; Galbraith, 1973, 1995; Mintzberg, 1979, 1989; O'Neill and Sackett, 1994; Egol *et al.*, 1995). The organic model of control --also known as the homeostatic model of control (Hofstede, 1978)-- can be characterized by its "lateral processes" (Galbraith, 1995), such as self-organization, decentralized decision making, and horizontal information flow, and the model is known to be effective in rapidly changing environments (Burns and Stalker, 1961). Figure 1.1 depicts the conceptual differences between the mechanistic and organic management control systems and

Table 1.1 summarizes the differences in characteristics between two control models. Mechanistic control relies on "vertical processes" in tall hierarchies where decisions and orders move down and reports move up; whereas, the organic model of control mainly depends on "lateral processes" in decentralized flat structures. In manufacturing, comparison between how Material Resource Planning (MRP, i.e. mechanistic) and *Kanban* (i.e. organic) systems work mirrors the essential differences between these two models of control.



Note: •Double-headed arrows are information flow: Vertical arrow symbolizes vertical information flow, while horizontal arrow represents horizontal flow of information.
•Triangle diagrams a structure of a system: Tall triangle represents a tall hierarchy structure, whereas short triangle represents a flat structure.

Figure 1.1 Mechanistic model of control vs. organic model of control

Characteristics	Mechanistic Management Control System	Organic Management Control System
Division of labor	clear	mixed
Structure	hierarchy	flat
Span of management decision	global (centralized)	local (distributed)
Primary interaction	vertical	lateral (horizontal)

Table 1.1 Characteristics of the mechanistic and organic management control systems

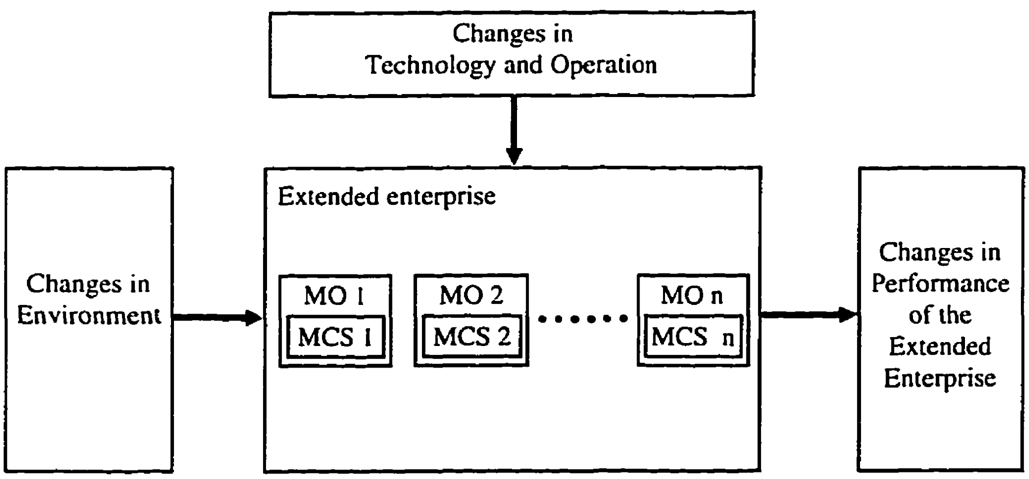
Interestingly, while new manufacturing forms are actively proliferating, there has been lack of research attention on the design of effective management control systems of these cooperative efforts (Abernethy and Lillis, 1995). As an alternative, a number of researchers have focused on the role of trust in managing such extended enterprises and have suggested trust would be able to replace the function of management control (Davidow and Malone, 1992; Kidd, 1994; CAM-I, 1995; Fukuyama, 1995; Goldman *et al.*, 1995; NGM, 1997). Trust, which is defined as "assured reliance on the character, ability, strength, or truth of someone or something" in Webster On-Line Dictionary(1997), becomes a necessary condition or prerequisite for such organizations working with heterogeneous manufacturing units, but trust alone is not sufficient to replace the function of control in such organizations. For example, the bankruptcy of Barings, a 232-year-old British bank, on February 23, 1995 due to a loss of $1 billion in futures trading by one employee (Brown, 1995) illustrates a case where trust as a function of control fails. Moreover, coordination of production activities across firms, the appropriate distribution of profits, coordination and finance of investments across firms, and assumption of responsibility for product liability are some of many issues remain unresolved regarding the management of such extended enterprises (Montgomery and Levine, 1996).

So far, most management control system design-related research efforts have been focused on intra-organizational control issues within a single (manufacturing) organization. However, as extended enterprises proliferate, inter-organizational control issues must also be addressed. A well designed management control system (or model) for a single firm may not promise the same effectiveness in an extended enterprise where heterogeneous or homogeneous management control systems must coexist and interact.

Designing an effective management control system is a complex and difficult process for any kind of organization (Flamholtz, 1996), however it is imperative to properly design or identify effective management control systems framework for extended enterprises, because it may significantly affect the organizations' success or failure.

1.2 Research Statement

Figure 1.2 diagrams the conceptual model for this study. Changing manufacturing technology in competitive environments provokes the need for individual manufacturing organizations to be adaptive and to change their management control systems accordingly. Alternative choices in individual firms' management control systems, namely mechanistic and organic management control systems, in turn affect the organizational performance of individual organizations in different environments (Burns and Stalker, 1961; Galbraith, 1973; Hofstede, 1978; Mintzberg, 1979; Cawsey *et al.*, 1994). Furthermore, as individual organizations form extended enterprises, the interactions of the mechanistic and/or organic management control systems of individual firms in an extended enterprise may determine the performance of the extended enterprise. Therefore, the focus of the research is two-fold: to investigate the impact of the interactions of mechanistic and/or organic management control systems within an extended enterprise on performance level of the extended enterprise in both stable and dynamic environments, and to demonstrate viability of both mechanistic and organic control system within an extended enterprise in both stable and dynamic environments.



Note: MO = Manufacturing Organization, MCS = Management Control System

Figure 1.2 Conceptual model of overview of the study

1.3 Thesis Outline

This thesis is divided into five additional chapters. Chapter 2 develops the framework of this research and presents various conceptual models of extended enterprises as well as several propositions of this study. Chapter 3 introduces several research hypotheses which examine fundamental premises of this research and describes the experimental design. Chapter 4 develops the implementation models of extended enterprises employed for this research. Chapter 5 presents the results and analysis. The discussion in this chapter includes the statistical results of the hypotheses and *post hoc* multiple comparisons using Scheffé tests to identify effective (or ineffective) frameworks of management control systems for an extended enterprise operating within a specific combination of contingent factors. Finally, Chapter 6 summarizes the results of this research, as well as discusses the implications of findings and the limitations of this research. Future research concludes this chapter.

CHAPTER TWO

Preliminary Research and Propositions

2.1 Introduction

Lack of research efforts on inter-organizational control and management issues led us to build a novel framework for this research mainly based on widely accepted, sound theories of intra-organizational control such as the study of Burns and Stalker (1961) which identified two pure forms of management control -- mechanistic and organic. Therefore, Section 2.2 identifies four possible types of basic interactions of the mechanistic and/or organic management control systems in an extended enterprise. Section 2.3 constructs conceptual models of extended enterprises which take a form of chain. Furthermore, prior to conducting our experiments, Section 2.4 attempts to predict the impact of the interactions of mechanistic and/or organic management control systems within an extended enterprise on performance of the extended enterprise in both stable and dynamic environments based on theories of chaos and self-organization.

2.2 Framework of the Research

Burns and Stalker (1961) proposed that the mechanistic model of control is effective in stable environments, while the organic model of control is effective in dynamic environments. This proposition is based on contingency theory which states that there is no one best way to organize or control organizations, but it depends on environments in which the organizations operate. There have been a few empirical studies that confirm this proposition (Woodward, 1965; Abernethy and Lillis, 1995). For example, Woodward's survey result of 100 British firms (1965) indicates that small batch organizations which mainly produce custom-design products employ flat organization structures with relatively little staff personnel; whereas companies with mass-production and stable technologies are mainly large and have tall management hierarchy. Senge (1996) also believes that organizations working in dynamic environments will eventually distribute power and authority to different subunits of organizations as long as they can coordinate their activities while avoiding chaos effects.

As Schonberger (1996) and NGM (1997) suggest, single manufacturing organizations cannot compete alone but need to orchestrate various manufacturing activities with partners in order to survive. Thus, we expect to see a number of heterogeneous manufacturing organizations establish supply chains or extended enterprises and work together in order to remain competitive. Therefore, we can consider the four possible types of basic partnerships (or interactions) between heterogeneous manufacturing units with respect to their management control systems as in Figure 2.1. Figures 2.2a, 2.2b, 2.2c, and 2.2d diagram four conceptual models of extended enterprises based on Figure 2.1.

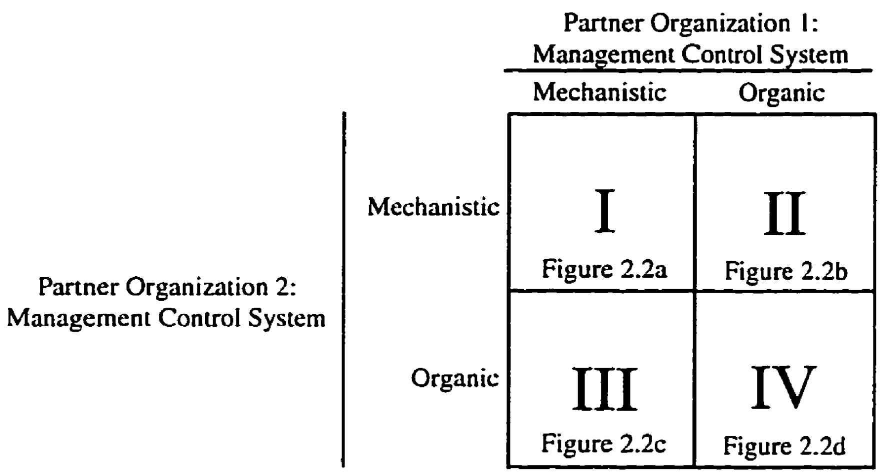


Figure 2.1 Four Types of Basic Partnership in terms of Management Control System

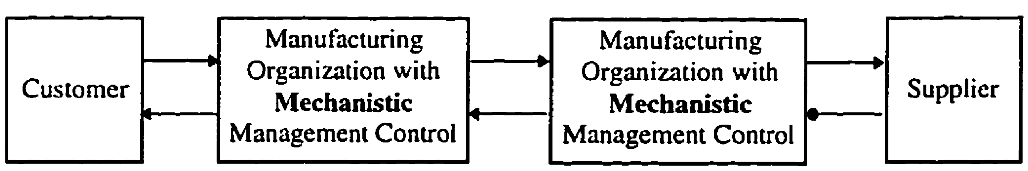


Figure 2.2a Conceptual model of an Extended Enterprise as in Cell I

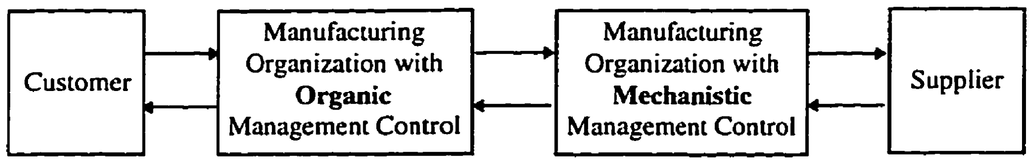


Figure 2.2b Conceptual Model of an Extended Enterprise as in Cell II

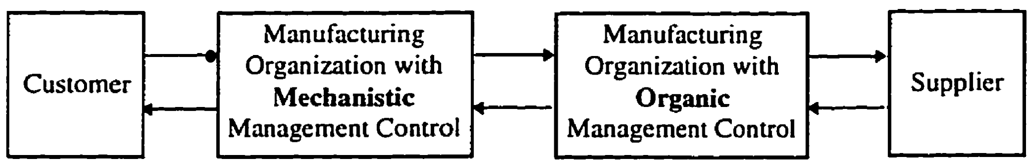


Figure 2.2c Conceptual Model of an Extended Enterprise as in Cell III

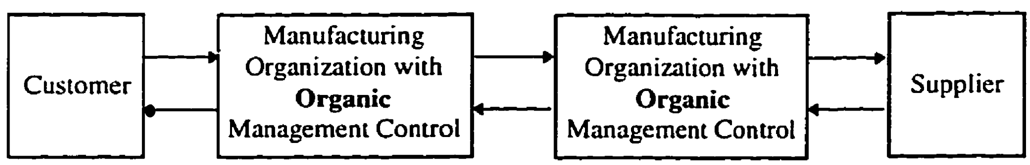


Figure 2.2d Conceptual Model of an Extended Enterprise as in Cell IV

Traditionally, cooperative efforts of different organizations are associated with the case of Figures 2.2a and/or 2.2c where a large mechanistic organization takes control and subcontracts work to other mechanistic organization(s) and/or to a small and usually organic organization(s) (Ching *et al.*, 1993; de la Sierra, 1995; Yoshino and Rangan, 1995). For example, General Motors (GM) traditionally was not willing to work with other firms if GM did not have majority control over a cooperative effort (Yoshino and Rangan, 1995). However, as business environments rapidly change and even become chaotic, we expect to see more, different kinds of, cooperative efforts as in Figures 2.2b and 2.2d.

2.3 Extended Enterprise Models

Based on the four conceptual models of extended enterprises, an extended enterprise can be structured differently according to the nature of tasks (i.e. cooperative efforts) that an extended enterprise faces. As individual manufacturing organizations become a part of an extended enterprise for a specific task type, each task can be categorized as follows: (1) unpartitionable sequential task, (2) partitionable sequential task requiring no communication, and (3) reciprocal task requiring communication. This categorization of nature of tasks is developed in accordance with Thompson's (1967) categorization of internal interdependence of organizational parts in complex organizations since extended enterprises intensely rely on interdependence of external organizational parts.

Furthermore, depending on the nature of tasks interdependence, different levels of cooperative effort are required as suggested by Brooks (1975) in the specific case of software development by a team of programmers. When a group of programmers work on partitionable complex tasks also known as reciprocal interdependence (Thompson, 1967), it requires high level of communication (i.e. coordination), whereas partitionable or unpartitionable sequential tasks also known as sequential interdependence (Thompson 1967), can be performed with little or no communication.

2.3.1 Extended Enterprise Model structured to perform unpartitionable sequential tasks

When a task cannot be partitioned and cannot be performed by more than one supply chain as in Figure 2.3, the task is an unpartitionable sequential task. For example, a situation where General Motors (GM) purchases engines from only one supply chain and assembles them into its automobiles describes a form of extended enterprise working on unpartitionable sequential tasks. Combining this extended enterprise model performing unpartitionable sequential tasks (Figure 2.3) with four basic conceptual models of extended enterprises in terms of interactions of management control systems (Figures 2.2a, 2.2b, 2.2c, and 2.2d), results in four different types of extended enterprise models as in Table 2.1.

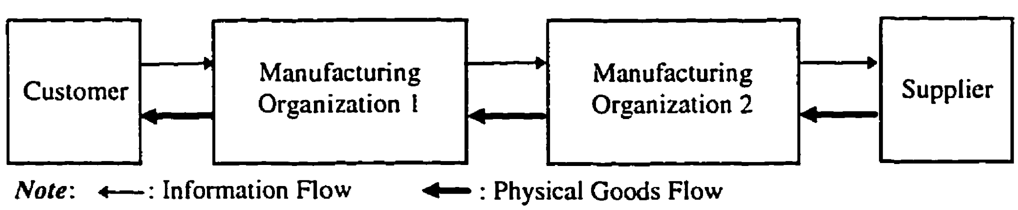
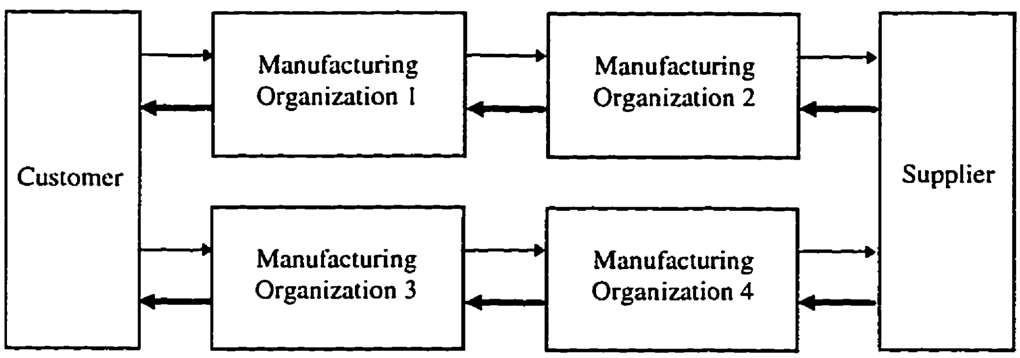


Figure 2.3 An Extended Enterprise model performing unpartitionable sequential tasks

2.3.2 Extended Enterprise Model structured to perform partitionable sequential tasks

Figure 2.4 diagrams an extended enterprise with two sub-supply chains working side by side on partitionable sequential tasks which require no communication between two sub-supply chains. For example, a scenario where GM purchases wheels from two sources, each with a different supply chain illustrates a form of cooperation of heterogeneous manufacturing units working on partitionable sequential tasks. Combining this extended enterprise model performing partitionable sequential tasks (Figure 2.4) with four basic conceptual models of extended enterprises in terms of interactions of management control systems, results in 16 different types of extended enterprise models as in Table 2.1.



Note: •Supply Chain I includes manufacturing organizations 1 and 2, and Supply Chain II includes manufacturing organization 3 and 4.
←: Information Flow ←: Physical Goods Flow

Figure 2.4 An Extended Enterprise model performing partitionable sequential tasks

However, 16 types of extended enterprises models are reduced to 10 since 6 pairs of models are identified as mirror images of each other. For example SMMOM and SOMMM are mirror images of each other, thus SMOMM, SMOOO, SOMMM, SOMMO, SOMOO, and SOOMM are removed. Please note that SMMOM, SOMMO, etc. are names used to represent various extended enterprise models. "S" represents the partitionable sequential tasks, and "M" and "O" denote the mechanistic and organic management control systems respectively. For example, SMOOM describes an extended enterprise structured to perform partitionable sequential tasks in which the Manufacturing Organization 1 uses the mechanistic control system, the Manufacturing Organization 2 uses the organic control system, the Manufacturing Organization 3 employs the organic control system, and the Manufacturing Organization 4 uses the mechanistic management control system.

2.3.3 Extended Enterprise Model structured to perform reciprocal tasks

Figure 2.5 illustrates an extended enterprise with two sub-supply chains working on reciprocal tasks requiring communication and cooperation. Communication and cooperation between two supply chains are required since the outputs (whether they be information or material) of each become inputs for the others. In order for Manufacturing Organizations 1 and 3 to complete their parts of the tasks, they need to share information and/or to exchange product parts as in Figure 2.5. For example, a situation where GM purchases parts from two suppliers, but requires their suppliers to work together in cooperative environment describes a form of an extended enterprise working on partitionable reciprocal tasks. Combining this extended enterprise model performing reciprocal tasks (Figure 2.5) with four basic conceptual models of extended enterprises, it results in 16 different types of extended enterprise models as in Table 2.1.

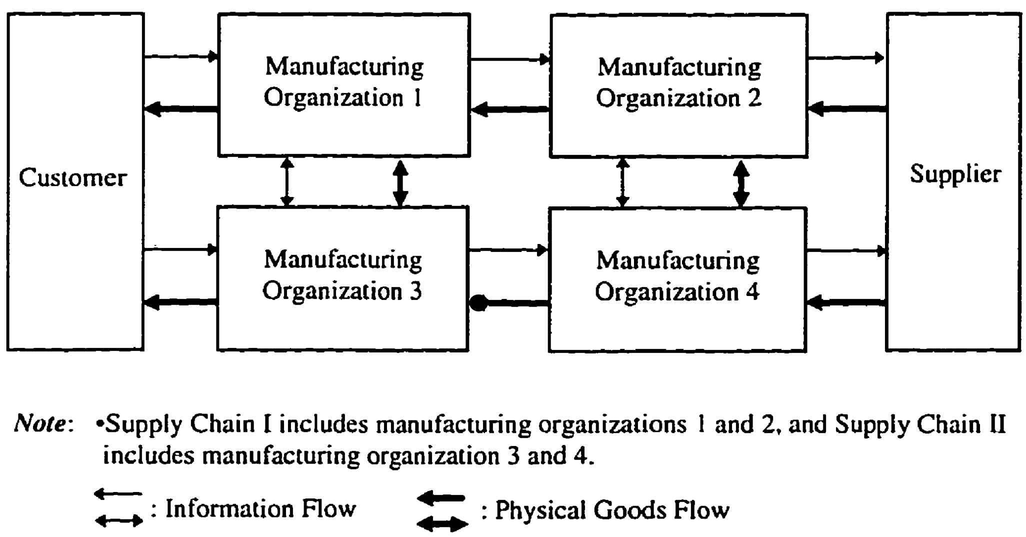


Figure 2.5 An Extended Enterprise model performing reciprocal tasks

However, 16 types of extended enterprises models are again reduced to 10 since 6 pairs of models are identified as mirror images of each other, thus RMOMM, RMOOO, ROMMM, ROMMO, ROMOO, and ROOMM are removed. (Note: "R" represents the reciprocal tasks.)

Table 2.1 lists all possible combinations of extended enterprise models combining four conceptual models of extended enterprises (as in Figures 2.2a, 2.2b, 2.2c, and 2.2d) and three structures of extended enterprises according to the nature of tasks.

Nature of tasks	Name[+]	Manufacturing Organization 1	Manufacturing Organization 2	Manufacturing Organization 3	Manufacturing Organization 4
unpartitionable	2MM	Mechanistic	Mechanistic	n/a	n/a
sequential	2MO	Mechanistic	Organic	n/a	n/a
tasks	2OM	Organic	Mechanistic	n/a	n/a
(UNPSEQ)	2OO	Organic	Organic	n/a	n/a
partitionable	SMMMM	Mechanistic	Mechanistic	Mechanistic	Mechanistic
sequential	SMMMO[a]	Mechanistic	Mechanistic	Mechanistic	Organic
tasks	SMMOM[b]	Mechanistic	Mechanistic	Organic	Mechanistic
(PSEQ)	SMMOO[c]	Mechanistic	Mechanistic	Organic	Organic
	SMOMM[a]	Mechanistic	Organic	Mechanistic	Mechanistic
	SMOMO	Mechanistic	Organic	Mechanistic	Organic
	SMOOM[d]	Mechanistic	Organic	Organic	Mechanistic
	SMOOO[e]	Mechanistic	Organic	Organic	Organic
	SOMMM[b]	Organic	Mechanistic	Mechanistic	Mechanistic
	SOMMO[d]	Organic	Mechanistic	Mechanistic	Organic
	SOMOM	Organic	Mechanistic	Organic	Mechanistic
	SOMOO[f]	Organic	Mechanistic	Organic	Organic
	SOOMM[c]	Organic	Organic	Mechanistic	Mechanistic
	SOOMO[e]	Organic	Organic	Mechanistic	Organic
	SOOOM[f]	Organic	Organic	Organic	Mechanistic
	SOOOO	Organic	Organic	Organic	Organic
reciprocal	RMMMM	Mechanistic	Mechanistic	Mechanistic	Mechanistic
tasks	RMMMO[g]	Mechanistic	Mechanistic	Mechanistic	Organic
(RECIP)	RMMOM[h]	Mechanistic	Mechanistic	Organic	Mechanistic
	RMMOO[i]	Mechanistic	Mechanistic	Organic	Organic
	RMOMM[g]	Mechanistic	Organic	Mechanistic	Mechanistic
	RMOMO	Mechanistic	Organic	Mechanistic	Organic
	RMOOM[j]	Mechanistic	Organic	Organic	Mechanistic
	RMOOO[k]	Mechanistic	Organic	Organic	Organic
	ROMMM[h]	Organic	Mechanistic	Mechanistic	Mechanistic
	ROMMO[j]	Organic	Mechanistic	Mechanistic	Organic
	ROMOM	Organic	Mechanistic	Organic	Mechanistic
	ROMOO[l]	Organic	Mechanistic	Organic	Organic
	ROOMM[i]	Organic	Organic	Mechanistic	Mechanistic
	ROOMO[k]	Organic	Organic	Mechanistic	Organic
	ROOOM[l]	Organic	Organic	Organic	Mechanistic
	ROOOO	Organic	Organic	Organic	Organic

Note: •Hereafter, each extended enterprise model is referred to as its name[+] indicated in the table.
•Each pair of conceptual duplicates models are indicated by superscripts on model names.

Table 2.1 36 Extended Enterprise Models

So far we have argued that increasingly individual manufacturing organizations are becoming parts of extended enterprises as competitive environments become dynamic, and the organic management control system --an alternative to the mechanistic control system-- is effective for intra-organizational control in dynamic environments. Then, can interactions of the mechanistic and/or organic management control systems effectively maintain patterns in organizational activities of an extended enterprise? What is the impact of different types of interactions of management control systems on performance measures such as inventory holding costs, stockout costs, number of order backlogs, and manufacturing cycle time variance (or the time from material receipt to product shipment)? Will the mechanistic management control system find no place in inter-organizational control in dynamic competitive environments? Answering these questions will help us build more effective frameworks of management control systems for extended enterprises.

2.4 Propositions

As international competitive pressures increase, business environments have been described as unpredictable, complex, turbulent, and even chaotic (Stacey, 1991; Goldman *et al.*, 1995; Champy, 1995). A number of researchers have attempted to apply the theories of chaos and self-organization developed by mathematicians, physicists, and biologists to understand and to explain behavior of dynamic business organizations in chaotic environments (Stacey, 1991; Kauffman, 1996). Chaos theory is concerned with finding "the order within the disorder of chaos" (Stacey, 1991) and self-organization, which is defined as "a process in which the components of a system in effect spontaneously communicate with each other and abruptly cooperate in coordinated and concerted common behaviour" (Stacey, 1991), is a process of managing behavior of dynamic systems in chaotic environments.

According to one theoretical biologist Kauffman (1996) who extends his study of chaos, self-organization, and the science of complexity in biology to economic and cultural systems, the optimal solution for an optimization problem of any complex system lies between order and chaos. He argues that "we will find an ordered regime where poor compromises for the entire organization are found, a chaotic regime where no solution is ever agreed on, and a phase transition between order and chaos where excellent solutions are found rapidly" (Ch 11, Kauffman, 1996).

A quality "guru" Juran (1995) made a similar argument about 45 years ago with respect to quality improvement. Juran argues that in order to improve quality, it is necessary for a manufacturing organization to undergo both static and dynamic phases. He uses a term "Control" to describe a static phase in which an organization devotes its energy to prevent changes, while a term "Breakthrough" to illustrate a dynamic period in which an organization devotes much energy to create changes. Neither "Control" nor "Breakthrough" alone can help a manufacturing organization to improve quality, but both are necessary for quality improvement of a manufacturing organization since "Breakthrough" creates good changes and "Control" prevents bad changes. Therefore, Juran also emphasizes the importance of a phase transition between order (i.e. "Control") and chaos (i.e. "Breakthrough") for solving optimization problems in the context of quality improvement.

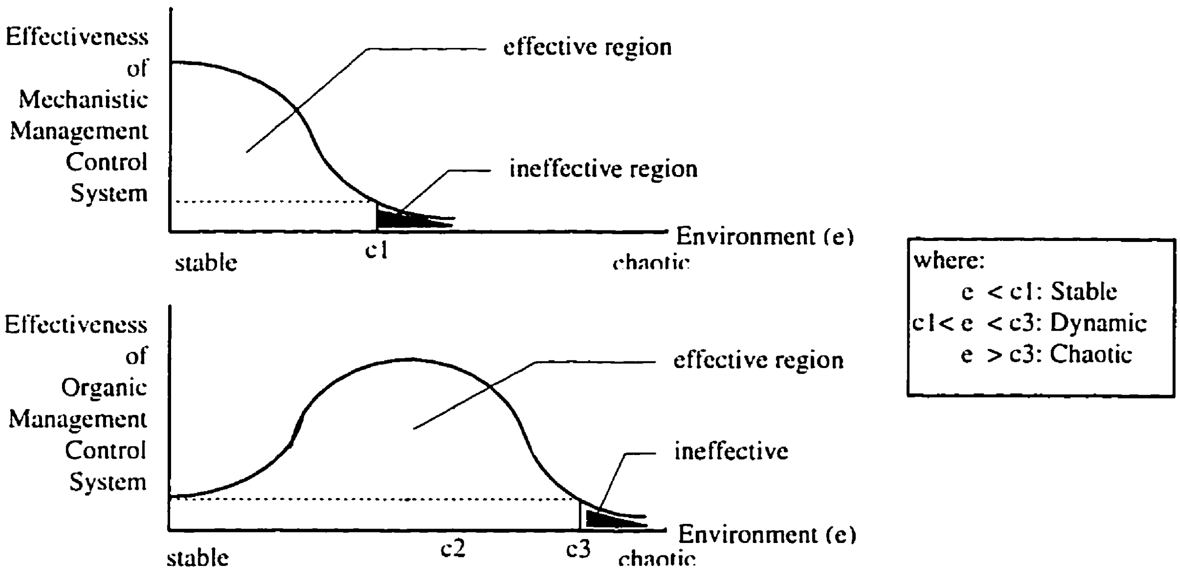


Figure 2.6 Effectiveness of mechanistic vs. organic management control system in various environmental conditions

The study of Burns and Stalker (1961) proposes that the mechanistic model of control is effective in relatively stable environments; whereas the organic model of control is effective in dynamic environments. From this proposition we might infer that the organic model of control is not as effective as the mechanistic one in relatively stable environments (see Figure 2.6), because fast responsiveness of the organic model of control may cause a manufacturing unit to overreact to minor changes in stable environments. Therefore, as presented in Figure 2.6, each model of management control system has a range where it is effective to help a single organization maintain patterns in organizational activities on a spectrum of environments between stable and chaotic. As well each model of control has its critical value (c1 and c3) on the spectrum in Figure 2.6 where it becomes ineffective to maintain organizational activities.

Then, do we expect that an extended enterprise organized with all mechanistically managed manufacturing units (as in Figure 2.2a) to outperform other extended enterprises with all organically managed firms (as in Figure 2.2d) in stable environments? As well, do we assume that only those extended enterprises organized with all organically managed manufacturing units (as in Figure 2.2d) eventually survive in dynamic environments? The answer to these questions are not simple according to general systems theory, "the whole is not the sum of its parts, but the product of these parts' interactions, all within a broader system" (Egol *et al.*, 1995). From this basis and Kauffman's argument, we propose the following propositions.

In relatively stable environments, interactions of either homogeneous management control systems as in Figures 2.2a and 2.2d or heterogeneous management control systems as in Figures 2.2b and 2.2c help an extended enterprise maintain its organizational activities, and further reach what Kauffman (1996) refers to an "ordered regime." Chaos is not evoked within extended enterprises operating in stable environments. Thus in stable environments, all four types of interactions of individual management control systems will help the extended enterprise (as in either Figure 2.2a, 2.2b, 2.2c, or 2.2d) find "a solution" to make its cooperative efforts work, but they may not motivate the extended enterprise to change and to reach a better solution (like an old saying advises "if it ain't broke, don't fix it").

> ***Proposition S.1***: In stable environments ($e < c1$), all four types of extended enterprise can maintain patterns in organizational activities in order to coordinate their cooperative efforts and keep them under control over time. However, none of the extended enterprises attempt to find a better way to keep its intra-organizational activities under control, even when there may be a better alternative solution.

Traditionally, even in stable environments, large organizations with mechanistic management control systems are known to be inefficient, but the inefficiency is compensated by the ease of centralized control in relatively stable and predictable world (Senge, 1996). As the world becomes unpredictable and dynamic, manufacturing organizations that stay with mechanistic management control systems become extremely inefficient and slow to maintain organizational activities, but centralized control still attempts to compensate. Therefore, in relatively dynamic environments, interactions of all mechanistic management control systems of individual manufacturing units in an extended enterprise as in Figure 2.2a help the extended enterprise maintain organizational activities inefficiently and slowly, but reach what Kauffman (1996) refers to an "ordered regime." In other words, interactions of mechanistic management control systems will help the extended enterprise find "a solution," but they may not motivate the extended enterprise to change and to reach a better solution. Being able to reach an "ordered regime" in stable environments for manufacturing organizations can be a competitive weapon, but in dynamic environments (such as point c2 in Figure 2.4) it is no longer a competitive advantage, but only a minimum requirement to be able to compete in a market. It can be compared to quality becoming an order-qualifier criteria from an order-winner criteria in the market since 1970s (Krajewski and Ritzman, 1992; Hill, 1994).

> ***Proposition D.1***: In dynamic environments, also known as complex environments ($c1 < e < c3$), when an extended enterprise is established with all mechanistically managed manufacturing units, interactions of mechanistic management control systems can help the extended enterprise maintain patterns in organizational activities in order to coordinate their cooperative efforts and keep them under control over time. However, interactions of mechanistic management control systems may not promise a competitive advantage over interactions of either the combination of the mechanistic and organic management control systems, or all the organic management control systems because of the inefficiency of the mechanistic management control systems in dynamic environments.

The organic model of control is identified as very effective for intra-organizational control in dynamic environments by Burns and Stalker (1961); however the organic model of control also can potentially lead a manufacturing organization to a constant state of flux or "system nervousness" (Orlicky, 1975). "System nervousness" is a term that describes an unstable system which constantly attempts to update its state faster than it is able to respond and therefore may never be able to stabilize due to delays in processing the inputs. Therefore, the organic management control system can potentially lead a manufacturing unit to become nervous as environments become chaotic. However, interactions of the organic and mechanistic management control systems as in Figure 2.2b and 2.2c in an extended enterprise may prevent the extended enterprise from becoming nervous, because the inefficiency of the mechanistic management control system in dynamic environments acts as a dampening mechanism to prevent the extended enterprise from reacting to minor changes in inputs. Thus, interactions of the mechanistic and organic management control systems may help the extended enterprise to reach rapidly what Kauffman (1996) refers to "excellent solutions." In other words, interactions of heterogeneous management control systems may help the extended enterprise find not only "a solution," but also excellent solutions.

> ***Proposition D.2.***: In dynamic environments, when an extended enterprise is established with manufacturing units with heterogeneous (mechanistic and organic) management control systems, interactions of fundamentally different management control systems can help the extended enterprise maintain patterns in organizational activities in order to coordinate their cooperative efforts and keep them under control over time. Interactions of heterogeneous management control systems may help motivate the extended enterprise to rapidly find a better way to keep its organizational activities in order.

However, the order of the heterogeneous mechanistic and organic management control systems in an extended enterprise may make a difference in performance of the extended enterprise reaching the "excellent solutions" in dynamic environments. Since the organic management control system is more effective in dynamic environments, an extended enterprise with the organic management control system near dynamic environments as in Figure 2.2b should be able to reach the "excellent solution" faster than the other extended enterprises organized as in Figure 2.2c.

> ***Proposition D.2.a***: In dynamic environments, interactions of heterogeneous mechanistic and organic management control systems of individual manufacturing units in an extended enterprise may help the extended enterprise to rapidly find an "excellent solutions" over time. However, having a manufacturing unit with the organic management control system closer to dynamic environments helps the extended enterprise reach "excellent solutions" more effectively than having a manufacturing organization with the mechanistic management control system close to dynamic environments.

As discussed above, a manufacturing unit with the organic management control system is potentially subjected to "system nervousness" in dynamic environments and an extended enterprise of manufacturing units with homogeneous organic management control systems as in Figure 2.2d is no exception. Therefore, depending on how dynamic the environments are, interactions of two organic management control systems may not help the extended enterprise to reach either an "ordered regime" or "excellent solution", but what Kauffman (1996) refers to a "chaotic regime." In other words, two organic management control systems may not help the extended enterprise find even "a solution," but may drive the extended enterprise into a constant state of flux.

> ***Proposition D.3***: In dynamic environments, when an extended enterprise is established with all organically managed manufacturing units, interactions of organic management control systems may not help the extended enterprise maintain patterns in organizational activities in order to coordinate their cooperative efforts and keep them under control over time depending on how dynamic are the environments.

Burns and Stalker (1961) would not agree with this last proposition since it directly challenges their fundamental proposition that the organic model of control is appropriate when the environment is dynamic. However, the new way of understanding behaviour of dynamic systems encourage us to challenge this traditional view of the organic model of control.

2.5 Summary

This chapter described the framework for this research. Section 2.2 identified four basic types of management control systems interactions based on two pure forms of management control system --the mechanistic and organic. Section 2.3 identified three types of extended enterprise models. Additionally, Section 2.4 developed five propositions to predict the impact of the interactions of mechanistic and/or organic management control systems within an extended enterprise on performance of the extended enterprise in both stable and dynamic environments based on theories of chaos and self-organization.

CHAPTER THREE

Hypotheses and Experimental Design

3.1 Introduction

In order to examine the propositions presented in Chapter 2, Section 3.2 introduces four basic research hypotheses. Hypotheses I, II, and III examine effects of each contingent factor of interest, namely environments, interactions of management control systems, and structures of extended enterprises, on the performance of an extended enterprise. Hypothesis IV investigates if the three contingent factors interact with each other, and in turn, if interactions of these three contingent factors have effects on the performance of an extended enterprise. These four hypotheses will examine our fundamental premises of this research that not only each contingent factor, but also the interaction between all three contingent factors together has effect on the performance of an extended enterprise. In Section 3.3, the experimental design for this research is discussed.

3.2 Research Hypotheses

> ***Hypothesis I* (H_1).** Different types of environments have no effect on the performance of an extended enterprise.

This null hypothesis tests if the performance level of extended enterprises are not significantly different in stable and dynamic environments. The performance of an extended enterprise is defined as the following three performance measurements: (1) the sum over all periods, of inventory holding costs and stockout costs in each period, (2) standard deviation of order delivery time over all periods, and (3) standard deviation of manufacturing cycle time (or the time from material receipt to product shipment) over all periods. While the first performance measurement is adopted from the Beer Distribution Game (Forrester, 1961; Sterman, 1989; Senge, 1990) which is the basis of the extended enterprise models, the other two measurements are selected from a list of performance measures that are becoming dominant measures in the manufacturing industry as identified by Arnuphaptrairong (1996).

According to Arnuphaptrairong (1996), Maskell (1989a, b, c & 1991) reported five types of performance measurements that are widely employed by world-class manufacturing and they were identified as measures of quality, delivery, production process time, flexibility, and costs. Among these types of performance measurements, measures of costs, delivery, and production process time are selected for this research since the simulation models developed for the study, which are described later in Chapter 4, quality and flexibility dimensions of the models are fixed.

The first performance measure is a traditional primary manufacturing performance measurement, which focuses on "measures of cost" (Arnuphaptrairong, 1996). This financial measurement of inventory and stockout costs has also been adopted to evaluate the performance of managerial behaviors in Beer Distribution Game (Sterman 1989). The second performance measurement, standard deviation of order delivery time, measures overall deviation of on-time delivery. The third measurement, standard deviation of manufacturing cycle time, measures production performance to order or the smoothness of the production flow (Arnuphaptrairong, 1996).

> ***Hypothesis II* (H_2).** Different types of interactions of the mechanistic and/or organic management control systems in extended enterprises have no effect on the performance of an extended enterprise.

This hypothesis tests if different types of interactions of the mechanistic and/or organic management control systems produce significantly different performance levels of extended enterprises. So far, several studies have implied that alternative choices in individual firms' management control systems, namely mechanistic and organic management control systems affect the organizational performance of individual organizations (Burns and Stalker, 1961; Galbraith, 1973; Hofstede, 1978; Mintzberg, 1979; Cawsey *et al.*, 1994). Based on this literature and on general systems theory, it is expected that the different types of interactions of mechanistic and/or organic management control systems in an extended enterprise should also effect the performance of the extended enterprise.

> ***Hypothesis III* (H_3).** Different structures of extended enterprises have no effect on the performance of an extended enterprise.

This hypothesis tests if the structural choice of extended enterprises based on the nature of tasks interdependence makes a difference in performance level of extended enterprises. According to Brooks' Law (1975), "adding manpower to a late software project makes it later" due to the added burden of communication, coordination effort, and coordination costs (Thompson, 1967). Analytically, it implies that for extended enterprises, the involvement of more and more companies does not necessarily lead to a stronger coverage of the problem due to the increased coordination requirement of the cooperative efforts. Thus, as the number of partners working on partitionable complex tasks increases, the cooperative effort or coordination cost increases, while the amount of work of an individual partner decreases. Therefore, from this hypothesis, it is expected that different structures of extended enterprises based on the nature of task interdependence effect on the performance of an extended enterprise.

> ***Hypothesis IV*** **(H_4).** Environments in which extended enterprises operate, interactions of the mechanistic and/or organic management control systems in extended enterprises, and structures of extended enterprises jointly do not affect the performance of an extended enterprise.

This formal hypothesis tests if there are significant interactions among environments in which extended enterprises operate, interactions of the mechanistic and/or organic management control systems in extended enterprises, and structures of extended enterprises. From this hypothesis, it is expected to examine effect of three contingent factors within an extended enterprise on the performance of the extended enterprise simultaneously, as well as to identify differences between different combinations of contingent factors.

Once these four hypotheses are tested, depending on the results of the tests, further investigation within each combination of three contingent factors will be performed using one-way analysis of variance (ANOVA) with *post hoc* Scheffé multiple comparison tests. The Scheffé test which is used for pairwise comparisons of means, is identified as the most conservative and requires larger differences between means for significance among the other multiple comparison tests (SPSS Inc., 1993). Thus, the Scheffé test will help us to identify effective frameworks of management control systems for an extended enterprise operating within a specific combination of contingent factors.

3.3 Experimental Design

In order to examine the hypotheses presented above, we have designed a series of experiments using the following contingent factors of interest and factor levels:

Factor 1: environments where an extended enterprise operates (two levels)
Factor 2: structures of an extended enterprise according to the nature of task (three levels)
Factor 3: interactions of the mechanistic and/or organic management control systems within a single supply chain in an extended enterprise (four levels)

Environments where an extended enterprise operates are either stable (level 1) or dynamic (level 2). For simplicity, dynamics of the environments is reflected by the fluctuation of customer demand. If the customer demand is constantly changing with large fluctuation, the environments are classified as dynamic, whereas if the customer demand is relatively predictable and constant then the environments are classified as stable. Figures 3.1 and 3.2 illustrate differences between dynamic and stable environments.

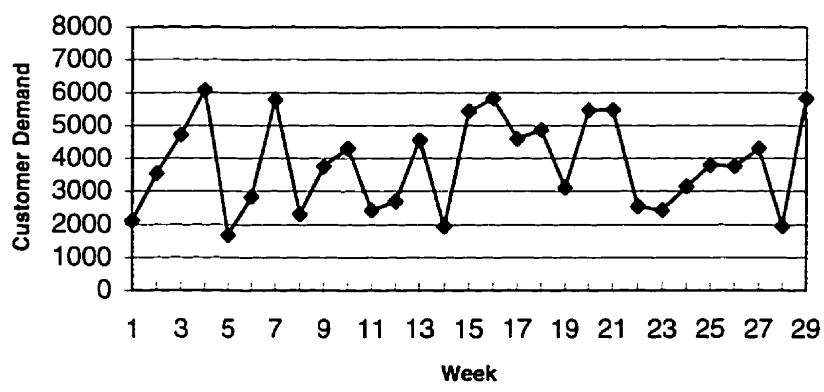


Figure 3.1 Customer demands representing a turbulent environment

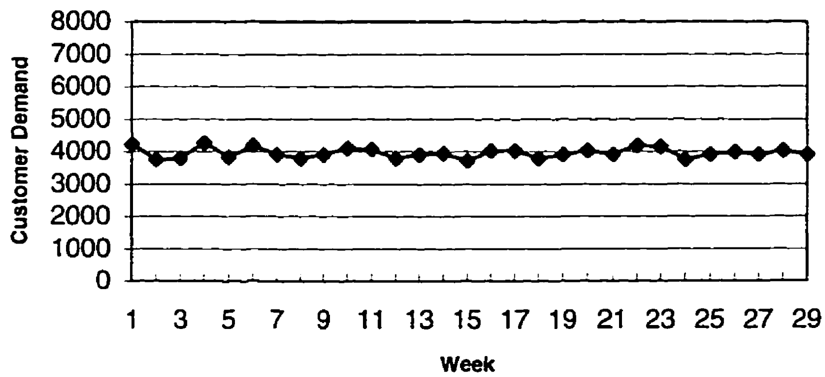


Figure 3.2 Customer demands representing a stable environment

The structure of an extended enterprise based on the nature of tasks is classified into three categories: (1) unpartitionable sequential tasks (level 1), (2) partitionable sequential tasks requiring no communication (level 2), and (3) reciprocal tasks requiring communication (level 3).

The third experimental factor of this research is interactions of the mechanistic and organic management control systems of a single supply chain within an extended enterprise. As we have discussed in Section 2.2, there are four levels of interactions of management control system. They are: (1) all mechanistic management control systems (level 1), (2) organic-then- mechanistic management control systems (level 2), (3) mechanistic-then-organic management control systems (level 3), and (4) all organic management control systems (level 4) (Note: level 2 places an organic management control system closer to the customer, while level 3 places a mechanistic management control system closer to the customer).

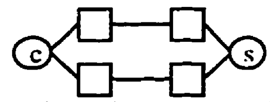
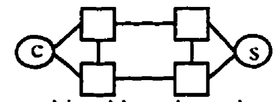
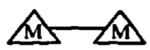
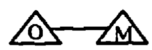
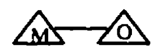
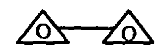
With these factors and factor levels, we have designed a series of experiments or factor settings. In fact, second and third experimental factors is first combined together to decide how many experiments are required to cover all the possible combinations of all three experimental factors.

Each supply chain within an extended enterprise in Figures 2.3, 2.4, and 2.5 can manage its operation with one of four types of interactions of management control systems, since level 1 of the second factor has one supply chain within its extended enterprise structure, four combinations of the first and second factors are identified. Level 2 of the second factor has two supply chains within its extended enterprise structure and thus it results 16 combinations (i.e. 4 • 4 = 16 factor settings). However, as identified in Section 2.3.2, 16 combinations are reduced to 10 since 6 pairs of combinations are identified as mirror images of each other. And level 3 of the second factor also has two supply chains within its extended enterprise structure and thus it results in 16 combinations, again reduced to 10. Thus, second and third factors together resulted in 24 experimental settings. These 24 experimental settings are replicated twice with two factor levels of the first experimental factor - environments. Therefore, a total of 48 experimental settings are required to cover all the possible combination of all three experimental factors (see Table 3.1). Table 3.2 illustrates 48 experimental settings where:

•Factor 1: Environments
  level 1: Stable (-)
  level 2: Dynamic (+)

•Factor 2: Types of Tasks
  level 1: Unpartitionable sequential (-)
  level 2: Partitionable sequential (0)
  level 3: Reciprocal (+)

•Factor 3: Interactions of Management Control Systems
  level 1: All mechanistic management control systems(-)
  level 2: Organic and mechanistic management control systems(x)
  level 3: Mechanistic and organic management control systems(0)
  level 4: All organic management control systems(+)

<table>
<tr><th>FACTORS</th><th colspan="12">FACTOR LEVELS</th></tr>
<tr><td>Factor 1: Environments</td><td colspan="6">Stable</td><td colspan="6">Dynamic</td></tr>
<tr><td>Factor 2: Structures</td><td colspan="4">
unpartitionable sequential tasks</td><td colspan="4">
partitionable sequential tasks</td><td colspan="4">
partitionable reciprocal tasks</td></tr>
<tr><td>Factor 3: Interactions of Management Control Systems</td><td colspan="3">
all mechanistic management control systems</td><td colspan="3">
an organic and a mechanistic management control system</td><td colspan="3">
a mechanistic and an organic management control system</td><td colspan="3">
all organic management control systems</td></tr>
<tr><td colspan="13">COMBINATIONS of FACTORS and FACTOR LEVELS</td></tr>
<tr><td>Combinations of Factors 2 & 3</td><td colspan="4"><u>4</u></td><td colspan="4"><u>$4 \bullet 4 - 6^{*} = 16 - 6^{*} =$ 10</u></td><td colspan="4"><u>$4 \bullet 4 - 6^{*} = 16 - 6^{*} =$ 10</u></td></tr>
<tr><td>Factor 1
•
Combinations of Factors 2 & 3</td><td colspan="4"><u>$2 \bullet 4 =$ 8</u></td><td colspan="4"><u>$2 \bullet 10 =$ 20</u></td><td colspan="4"><u>$2 \bullet 10 =$ 20</u></td></tr>
<tr><td>Total Experiments</td><td colspan="12"><u>$8 + 20 + 20 =$ 48</u></td></tr>
</table>

Note: C: Customer S: Supplier □: Manufacturing Organization * number of mirror image

△M: Mechanistic Management Control System △O: Organic Management Control System

Table 3.1 Number of total experiments

Factor Combinations	Factor 1 Environments	Factor 2 Type of Tasks	Factor 3 Interactions of Management Control Systems	
			Supply Chain I	Supply Chain II
1	-	-	-	-
2	-	-	-	x
3	-	-	-	0
4	-	-	-	+
5	-	-	x	x
6	-	-	0	x
7	-	-	0	0
8	-	-	+	x
9	-	-	+	0
10	-	-	+	+
11	-	+	-	-
12	-	+	-	x
13	-	+	-	0
14	-	+	-	+
15	-	+	x	x
16	-	+	0	x
17	-	+	0	0
18	-	+	+	x
19	-	+	+	0
20	-	+	+	+
21	-	0	-	N/A
22	-	0	x	N/A
23	-	0	0	N/A
24	-	0	+	N/A
25	+	0	-	N/A
26	+	0	x	N/A
27	+	0	0	N/A
28	+	0	+	N/A
29	+	-	-	-
30	+	-	-	x
31	+	-	-	0
32	+	-	-	+
33	+	-	x	x
34	+	-	0	x
35	+	-	0	0
36	+	-	+	x
37	+	-	+	0
38	+	-	+	+
39	+	+	-	-
40	+	+	-	x
41	+	+	-	0
42	+	+	-	+
43	+	+	x	x
44	+	+	0	x
45	+	+	0	0
46	+	+	+	x
47	+	+	+	0
48	+	+	+	+

Table 3.2 48 factor combinations for the experiment

With 48 experimental setting, each factor setting is replicated 50 times for statistical analysis. Power analysis is used to determine a number of data sets of each 48 factor settings that is required to produce the probability that a statistical test would result in statistical significance (i.e. statistical power). Power analysis is performed using Power Analysis and Sample Size (PASS), version 6.0 for Microsoft Windows to calculate power and determine sample size (Hintze, 1996).

The result of power analysis with $\alpha = 0.05$ and $\beta = 0.01$ indicated that a sample size as small as 12 would produce a statistically powerful result; however in order to assure a strong power on statistical analysis of the experimentation, a sample size of 50 is used in the experimentation. Therefore, 2,400 data sets were generated for statistical tests and analysis.

3.4 Summary

This chapter presented four basic research hypotheses which examine the fundamental premises of this research. Section 3.2 introduced these four hypotheses and also the three dependent variables employed to measure organizational performance: the sum of inventory holding costs and stockout costs, standard deviation of order delivery time, and standard deviation of manufacturing cycle time. Finally, Section 3.3, the experimental design for this research was discussed.

The next chapter discusses the implementation models of extended enterprises and methodologies for investigating the hypotheses and propositions of this research.

CHAPTER FOUR

Model Description and Research Methodology

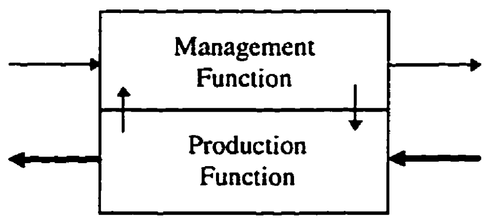
4.1 Introduction

In order to examine the hypotheses presented in Chapter 3, a generic model of a manufacturing system is developed in this chapter. However, prior to modeling any dynamic system, it is important to define the purpose of the model, because having a clear statement of model purpose helps establish boundaries of the model and thus to identify all relevant structural relationships (Starr, 1980). And eventually, a clear statement of model purpose is used as an important model validation measure which in turn, helps examine if all the important concepts and structural relationships for addressing the purpose of the model are included in the model (Forrester and Senge, 1980; Starr, 1980). Therefore in this chapter, we describe, build, and validate the implementation models of extended enterprises employed for this research. From Sections 4.2 to 4.7, a description of the two basic manufacturing system models (which are basic building blocks of the extended enterprise models) is discussed. Finally, the implementation models of extended enterprises are constructed using the two basic manufacturing system models in Section 4.8. Section 4.9 presents the results of the validation tests for the extended enterprise models.

4.2 Basic Manufacturing System Model Description

The basic manufacturing system model should be able to demonstrate how well a manufacturing organization satisfies the customer's demands with regard to different types of management control systems in different competitive environments. Organizational structure, the delay in decisions and actions, and the policies governing productions and inventories together constitute a manufacturing management control system. Therefore, the model should demonstrate how effective different choices of management control systems are in satisfying changing customer's demands.

Generally, a basic manufacturing system can be described as a framework consisting of two functions (see Figure 4.1). The management function (i.e. the manufacturing management control system) collects information (e.g. customer demand, inventory report etc.) to make operational decisions and communicate decisions (e.g. orders) to the production function (e.g. shop floor). Then the production function produces products according to the decisions from the management function and reports result to the management function.



Note: •Narrow arrows represent information flow such as orders and reports.
•Thick arrows represent physical goods flow such as material and products.

Figure 4.1 Basic Manufacturing System Framework

With this system framework, we construct a general manufacturing system model which represents the primary processes common to all manufacturing systems based on Forrester's description of production-distribution system (Forrester, 1961). It uses the following assumptions.

1. A manufacturing system consists of the management function (e.g. management control system) and the production function (e.g. production line).
2. Manufacturing tasks can be subdivided into marketing and production processes.
3. All firms have access to identical technology and therefore technology is not a limiting factor.
4. Individual manufacturing systems use Make-to-Stock (MTS) strategy, in which the manufacturing firms hold inventory in stock for immediate delivery.

According to Woodward (1961), the manufacturing tasks of a small production system is essentially composed of marketing, development, and production processes. First the marketing process recognizes or identifies the order or need for a new product from the customer. Then the development process develops and designs the product. The production phase of the manufacturing tasks follows. However, the development process is not included in the manufacturing cycle of our basic manufacturing system model, since we assume that the product exists and the technology to build new items is readily available to produce the products that the customer wants as suggested by Hill (1994).

Based on the above assumptions and the manufacturing system framework in Figure 4.1, we have built two models of basic manufacturing system, one with a mechanistic management control system and another one with an organic management control system. Different sets of organizational structure, delays in decisions and actions, and policies governing productions and inventories which constitute management control systems (i.e. the management function in Figure 4.1) are incorporated in the two models based upon Burns and Stalker's (Ch 6, 1961) descriptions of two management control systems. Table 4.1 identifies these key characteristics and how the mechanistic and organic models approach them.

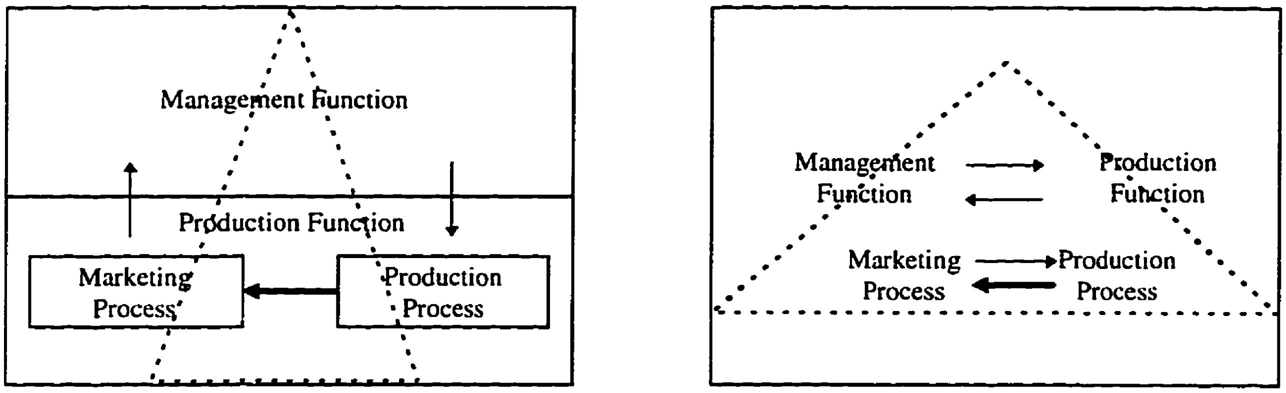
The manufacturing organization model with the mechanistic management control system has constructed with the following characteristics: (1) distinctive divisions of labor within and between management and production functions are clear and observable, (2) organizational structure is hierarchical with management at the top setting policies governing purchases, production, and inventories, as well as making operational decisions (i.e. local judgment is minimized), and (3) decisions and orders transmit down and result reports move up in the hierarchy (i.e. vertical communication is emphasized).

The manufacturing organization model with the organic management control system is designed with the following characteristics: (1) divisions of labor within and between management and production functions are not clearly defined, (2) organizational structure is flat with purchasing, production, and inventory policies setting and decision making decentralized (i.e. local judgment is maximized), and (3) local interactions among decentralized components is maximized (i.e. horizontal communication is emphasized).

Characteristics	Mechanistic Model of Management	Organic Model of Management
Premise	the specialized differentiation of functional tasks into which the problems and tasks facing the company as a whole are broken down, but centrally controlled	the problems and tasks facing the company as a whole are approached from the contributive nature of special knowledge and experience, and locally controlled
Nature of individual task	the abstract nature of each individual task, which is pursued with techniques and purposes more or less distinct from those of the company as a whole	the holistic nature of the individual task, which is seen as set by the total situation of the company
Definition of task	the reconciliation, for each level in the hierarchy, of those distinct performances by the immediate superiors	the adjustment and continual re-definition of individual tasks through interaction with others
Definition of rights, obligations, and methods	a precise definition of rights, obligations, and technical methods is attached to each functional role, to minimize local judgment	no precise definition of rights, obligations, and detailed technical methods is attached to each functional role, thus to use employee skills and promote local judgment
Location of responsibilities	the translation of rights and obligations and methods into the responsibilities of a functional position is top-down	the spread of commitment to the company is beyond any technical definition
Structure of control, authority, and communication	hierarchic structure of control, authority, and communication	a network structure of control, authority, and communication.
Location of knowledge	a reinforcement of the hierarchic structure by the location of knowledge being exclusively at the top of the hierarchy, where the final reconciliation of distinct tasks and assessment of relevance is made	knowledge about the technical or commercial nature of the here and now task may be located anywhere in the network; this location becomes the *ad hoc* center of control authority and communication for the task
Communication channel	a tendency for interaction between members of the company to be vertical, i.e. between superior and subordinate	a lateral rather than a vertical nature of communication between people of different rank, i.e. consultation rather than command
Content of communication	instructions and decisions issued by superiors governing operations and working behavior	content of communication consists of information and advice rather than instructions and decisions
Condition of membership	insistence on loyalty to the company and obedience to superiors as a condition of membership	commitment to the organization's tasks and to continuous improvement is more highly valued than loyalty and obedience
Value of knowledge	a greater importance and prestige attaching to internal (local) than to general (cosmopolitan) knowledge, experience, and skill	importance and prestige attach to affiliations and expertise valid in the industrial, technical, and commercial milieux external to the firm

Table 4.1 Characteristics of the mechanistic and organic management control systems
(adopted from Burns and Stalker 1961)

Figure 4.2 diagrams the differences between these two conceptual models of manufacturing system with the mechanistic and organic management control systems.



A manufacturing organization model with the mechanistic management control system

A manufacturing organization model with the organic management control system

Note:
- •Distinctive divisions of labor are represented by boxes and solid lines.
- •Dotted triangles represent structures of organizations. Tall triangle represents a tall hierarchy structure, whereas short triangle represents a flat structure.
- •Thin arrows represent communication.
- •Thick arrows represent physical goods flow.
- •Location of individual functions and processes in a manufacturing organization with the mechanistic management control system is fixed by its nature (see Table 3.1)
- •Location of individual functions and processes in a manufacturing organization with the organic management control system is not fixed and is determined as the *ad hoc* center of control authority and communication for the task (see Table 3.1)

Figure 4.2 Conceptual models of manufacturing organizations

4.3 Research Methodology

According to Galbraith (1973) and Cawsey *et al.* (1994), there are two schools of thought regarding structuring and managing organizations. The first school of thought believes that there is one universal approach that applies in all circumstances, while the second school of thought subscribes to the idea that there is no one "best" way to organize and manage organizations, but the choice is contingent on internal and external environments in which the organizations operate. The contingent approach on management control system design has become one of the dominant research methods (Dent, 1990; Fisher, 1995).

However, research on management control systems design based on the contingent approach often fails to study multiple contingent factors and control system attributes simultaneously that are essential in determining the effectiveness of control system design (Fisher, 1995). This can be attributed to the inappropriateness of the conventional contingency theory methodologies (Fisher, 1995).

Therefore we have implemented a system dynamics (SD) simulation model –also known as "microworld" (Morecroft, 1988) or "management laboratory" (Forrester, 1961)-- as our methodology for this research. The SD simulation model will help us to understand the interrelationships between multiple contingent variables and control system attributes simultaneously in compressed time and space. However, the study is not intended to give answers to specific "how to" and/or "what to" questions regarding design of new effective management control systems for a specific extended enterprise. SD simulation models are not simulations of reality, but are simplified manipulable worlds "specially designed to highlight (and make accessible) particular concepts and particular ways of thinking" (Resnick, 1994) or as Papert (1980) describes the microworlds are "incubators for knowledge." Therefore, this research will help us develop (1) a deeper understanding of "why" manufacturing organization may need newly designed management control systems, and (2) a general direction to effectively structuring heterogeneous management control systems within extended enterprises depending upon internal and external environments.

There are alternative methodologies available for the research, such as empirical research, survey research, and different types of simulation. Each alternative method has proven to be a powerful tool for a certain class of problems, but they fail to address some of the following requirements for the study: (1) incorporation of nonlinear relationships, (2) holistic approach to the system analysis rather than cross sectional analysis, and (3) examination on dynamics and feedback relationships (Forrester, 1968; Fisher, 1995). SD, as its name implies, "is concerned with creating models or representations of real world systems of all kinds and studying their dynamics (or behaviour)" (Wolstenholme, 1990). Thus, system dynamics modeling and simulation tools are especially useful with "improving (controlling) problematic system behaviour" (Wolstenholme, 1990) and this idea is supported by many system dynamics researchers (Forrester, 1961; Senge, 1990; de Geus, 1992; Bakken *et al.*, 1992). Thus, system dynamics (SD) is the platform of the research.

For the implementation of our system dynamics (SD) simulation models, we have used the *ithink*® Analyst software version 4.0.2. for Windows which provides "a hierarchical, multilayer environment incorporating graphical tools to support conceptualization, construction, analysis, and communication activities" (Peterson, 1992; High Performance Systems, 1996) on a IBM compatible Pentium PC. In order to develop better understanding of SD and gain familiarity with *ithink*® software package, we have built, tested, and verified a benchmark model - the classic Beer Distribution Game (Sterman, 1989; Ch.3, Senge, 1990) using *ithink*®. The qualitative verification of the model validity was performed by answering a set of questions introduced by Forrester and Senge (1980). The verification procedure of SD model will be discussed in Section 4.7.

4.4 Implementation Models of the Basic Manufacturing Systems

Prior to discussing the specific structure of basic manufacturing system models, we will briefly discuss the general structures that are common in all dynamic systems.

4.4.1 General Structure of Dynamic Systems

A system can have either opened- or closed-boundary (Forrester, 1969). However in order to investigate a particular system behavior of interest in controlled environments, the boundary must be set so that the system behavior of interest is not imposed exogenously, but created endogenously within the boundary of the system (Forrester, 1970). An adequately set boundary with a clear system or model purpose should separate all relevant structural relationships from the ones that are irrelevant to the study (Starr, 1980). Figure 4.3 diagrams the closed-boundary concept (Forrester, 1970).

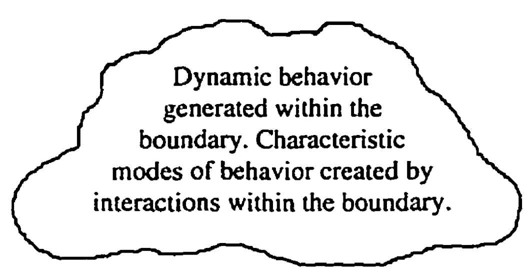


Figure 4.3 Closed boundary defining a dynamic system (Adopted from Forrester, 1970)

Within the closed-boundary of a system, dynamic behaviors of a system can be modeled using the four elements in the hierarchies presented below (adopted from Forrester, 1970):

e.0 Closed boundary around the system
- e.1 Feedback loops as the basic structural elements within the boundary
  - e.1.1 Level (state) variables representing accumulations within the feedback loops
  - e.1.2 Rate (flow) variables representing activity within the feedback loops
    - e.1.2.1 Goal
    - e.1.2.2 Observed condition
    - e.1.2.3 Detection of discrepancy
    - e.1.2.4 Action based on discrepancy

    as components of a rate variable

Feedback-loops (e.1) are basic building blocks of all systems (Forrester, 1968, 1969, 1970). A simple feedback-loop structure is composed of one level variable (e.1.1) and one rate variable (e.1.2). Figure 4.4 illustrates the simplest possible feedback-loop structure. Figure 4.5 is an *ithink*® generated diagram of Figure 4.4. Wolstenholme (1990) defines level variables (e.1.1) as "the measurable quantities of any resource in a system at any point in time" such as population and inventory, and rate variables (e.1.2) as "control variables which directly increase or deplete resource levels" such as birth rate and shipping rate. Level variables (e.1.1) are changed only by rates of flow, and the rate variables (e.1.2) are expressed in equations and represent the statement of system policy which determines the rates of flow between the various levels of the system (Forrester, 1968, 1969, 1970).

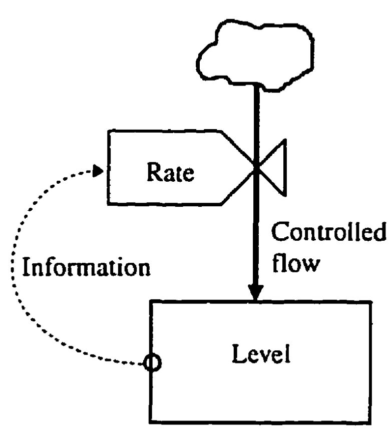


Figure 4.4 Simplest possible feedback loop having one rate and one level
(Adopted from Forrester, 1970)

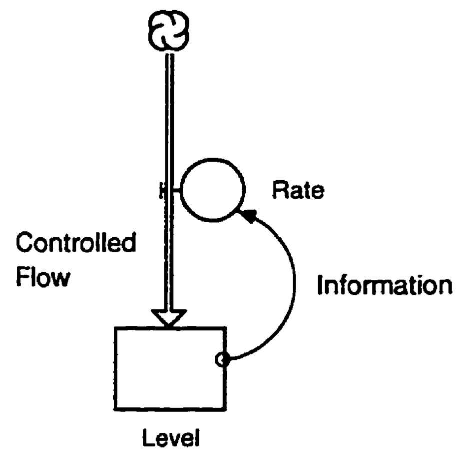


Figure 4.5 ***ithink*®** **generated diagram of simplest possible feedback loop having one rate and one level**

Further, in order for rate variables to influence level variables, four components of rate variables --goal (e.1.2.1), observed condition (e.1.2.2), detection of discrepancy (e.1.2.3), and action (e.1.2.4) based on discrepancy-- must be identified. A goal can be viewed as the desired state of a level and an observed condition can be viewed as the current state of the level. When a difference between the goal and the observed condition is detected (i.e. detection of discrepancy), an action based on a system policy or rule should be manipulated by the rate variable to correct the discrepancy (i.e. action based on discrepancy).

A thermostat best describes a system which utilizes a feedback-loop structure in a closed boundary (i.e. the room). A thermostat measures the current temperature of the room (i.e. level or state variable). and compares the current temperature (i.e. observed condition) with a preset standard of what the room temperature should be (i.e. goal). Then if the actual room temperature is higher than the preset standard room temperature (i.e. detection of discrepancy), the thermostat transmits the information through a communications network to cause the heating device to be turned off (i.e. action based on discrepancy) forcing the rate variable to change until the room temperature reaches the preset temperature.

Using the general concepts of dynamic systems' structure presented above, we discuss more specific structures of basic manufacturing organization models for the study in the next section.

4.4.2 Structuring of Basic Manufacturing Organization Models

Based on Forrester's original production-distribution model (Forrester, 1961; Sterman, 1989; Senge, 1990) and on the conceptual models presented in section 4.2, we designed two general classes of a manufacturing organization with a primary production function common to both models and with two distinctive management control systems representing management function. Thus in the following sections, we describe two primary level variables and three rate variables of the base model.

4.4.2.1 Level Variables of a Basic Manufacturing Organization Model

Level variables are "the accumulations within the system" (Forrester, 1961) resulting from the flows in and out of the level variables. All level variables can be expressed in an equation similar to the classic inventory balancing equation (L.0) as follows.

$$\begin{aligned} \textit{Ending Inventory} &= \textit{Beginning Inventory} + (\textit{Products Produced - Product Sold}) \quad \text{(L.0)} \\ &= \textit{Beginning Inventory} + (\textit{Production Rate - Demand Rate}) * \textit{time} \end{aligned}$$

There are two level variables of interest in the basic manufacturing organization models: *Inventory* and *Order Backlog*.

Inventory **(I_t).** The *Inventory* level variable is the quantity of goods on hand at a specific time t. In order to determine how many units are on hand at time t, it is necessary to add number of units produced and to subtract number of units sold (or shipped out) to the customer between time t-1 and t from the initial inventory. The following equation (L.1) represents the *Inventory* at time t:

$$I_t = I_{t-1} + (PR - SR) * dt, \qquad I_t \geq 0 \qquad \text{(L.1)}$$

where I_t = *Inventory*
PR = *Production Rate*
SR = *Shipment Rate*
dt = *"delta time" which is the time interval between t-1 and t*

Order Backlog (OB_t). The *Order Backlog* level variable represents the accumulation of customer orders not yet delivered due to low or zero *Inventory*. Thus, the *Order Backlog* level variable at a specific time t is calculated by adding the number of incoming customer orders and subtracting the number of products shipped out to the customer between time t-1 and t from the initial number of order backlog. The following equation (L.2) is the *Order Backlog* equation:

$$OB_t \;=\; OB_{t-1} + (OR - SR) * dt, \qquad OB_t \geq 0 \qquad \text{(L.2)}$$

where OB_t = *Order Backlog*
OR = *Order Rate*
SR = *Shipment Rate*
dt = *"delta time" which is the time interval between t-1 and t*

Although *Inventory* and *Order Backlog* level variables exist separately in the manufacturing organization, they are closely related to each other through *Shipment Rate(SR)*. When *SR* becomes 0 due to low or zero *Inventory* level, *Inventory* and *Order Backlog* levels are increased by *Production Rate (PR)* and *Order Rate (OR)* respectively. Conversely, as *SR* becomes positive, both *Inventory* and *Order Backlog* levels are decreased by *SR*.

In *Inventory* level equation (L.1) and *Order Backlog* level equation (L.2), we have identified three primary rate variables of interest in the basic manufacturing organization model: (1) *Production Rate*, (2) *Order Rate*, and (3) *Shipment Rate*. Rate variables --also known as the "decision functions" (Forrester, 1961)-- determine flows in and out of level variables, therefore various management policies which govern individual flow rates are presented as well.

4.4.2.2 Rate Variables of a Basic Manufacturing Organization Model

Production Rate (PR). *Production Rate* at time t is determined by production and inventory policy. Basically, production policy attempts to compensate for the amount of products shipped (*Shipment Rate:* SR_{t-1}) at time t-1, and also to make a necessary adjustment on inventory- and pipeline-deficit situations. Individual manufacturing systems are assumed to use Make-to-Stock (MTS) strategy, in which the manufacturing firms hold inventory in stock for immediate delivery. Thus, individual manufacturing units set their *Target Inventory (TI)* levels well above a weekly customer demand (i.e. *Order Rate*). *Target Inventory (TI)* level is, hence, set by the *President* and is simply a multiple of *Order Rate (OR)* according to the inventory policy adopted from the Beer Distribution Game (Sterman, 1989; Senge 1990). And summation of the difference between *TI* and *I*, and *Order Backlog (OB)* level at time *t* indicates how many more units should be in the *I* to satisfy the customer demand. The difference between *OR* and *PR* determines how many units are currently in production process (i.e. in production pipeline) to satisfy the customer demand and to meet the target inventory level (*TI*). However, it is assumed that management does not respond immediately to the full extent of any adjustment required due to these two deficit terms (Forrester, 1961). Thus this adjustment term,

$$[\{(TI_t - I_t) + OB_t\} + (OR - PR) * dt]$$

is multiplied by *1/k*, which is a time constant representing the rate at which management, on average, reacts. This *1/k* is similar to a smoothing parameter, alpha (α) of the exponential smoothing forecasting method for customer demand. "Larger α values emphasize recent demands and result in forecasts more responsive to changes in the underlying average, while smaller α values treat past demand more uniformly and result in more stable forecasts" (Krajewski and Ritzman, 1992) and the same argument is true for *1/k*.

As the final step, the *MAX* function is used to prevent *Production Rate* from taking on negative values since *PR* must always be greater than or equal to zero. The following is the *Production Rate* equation (R.1):

$$PR = MAX(0, [(SR * dt) + (1/k)*\{[(TI_t - I_t) + OB_t] + (OR - PR) * dt\}]) \qquad \text{(R.1)}$$

where

PR	=	*Production Rate*
I_t	=	*Inventory*
TI_t	=	*Target Inventory*
OB_t	=	*Order Backlog*
OR	=	*Order Rate*
SR	=	*Shipment Rate*
$1/k$	=	*reaction rate*
dt	=	*"delta time" which is the time interval between t-1 and t*

Order Rate (OR). *Order Rate* is determined by the customer demand in each period. There is no equation for *OR*, as the customer order received in each period sets the *OR*. *Order Rate* in the model is randomly chosen per period from a uniformly distributed function.

Shipment Rate (SR). *Shipment Rate* at time t is determined by *OR*, I_t, and OB_t. If the manufacturing organization has sufficient *Inventory* (i.e. I_t) to satisfy the unfilled order (i.e. OB_t) and the current period's customer order (i.e. *OR*), then the manufacturing organization ships the amount equal to the sum of OB_t and *OR*, and the shipped amount becomes the current period's sale. But, if the *Inventory* level is lower than the sum of the two terms and greater than zero, then manufacturing ships out the total number of units in *Inventory* to fulfill a part of the unfilled order (i.e. OB_t) and/or current period's customer demand. The following equation (R.2) represents the *Shipment Rate* at time t:

$$SR_t = \begin{cases} (OB_t + OR_t), & if\,(OB_t + OR_t \leq I_t) \\ I_t, & if\,(OB_t + OR_t > I_t) \end{cases} \qquad \text{(R.2)}$$

Figure 4.6 diagrams the principal level and rate variables which are common to both models within a closed-boundary. The two rectangles represent the system level variables and four valve symbols depicts the principal rate variables. The solid arrows represent the material flows into and out of levels and the arrows with circles describe the order flows. The cloud symbols represent the sources or sinks of flows coming from or going to the outside environment or boundary.

Figure 4.7 is an *ithink*® generated diagram of Figure 4.6. Rectangles represent the level variables and either circles alone or circles and rectangles with vertical lines (called "conveyors") together represent the rate variables. "Conveyor"' is a conceptual moving sidewalk or conveyor belt which transfers material or products either from level to level, cloud to level, or level to cloud in a certain period of time thus, in order to implement rate variables between two level variables or between a level variable and a cloud, it is necessary to use Conveyor in *ithink*®.

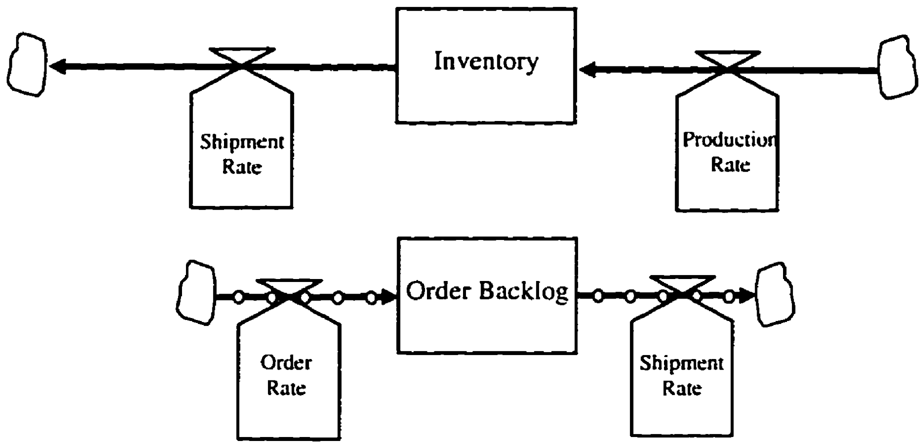


Figure 4.6 The major levels and rates for the model of a basic manufacturing organization

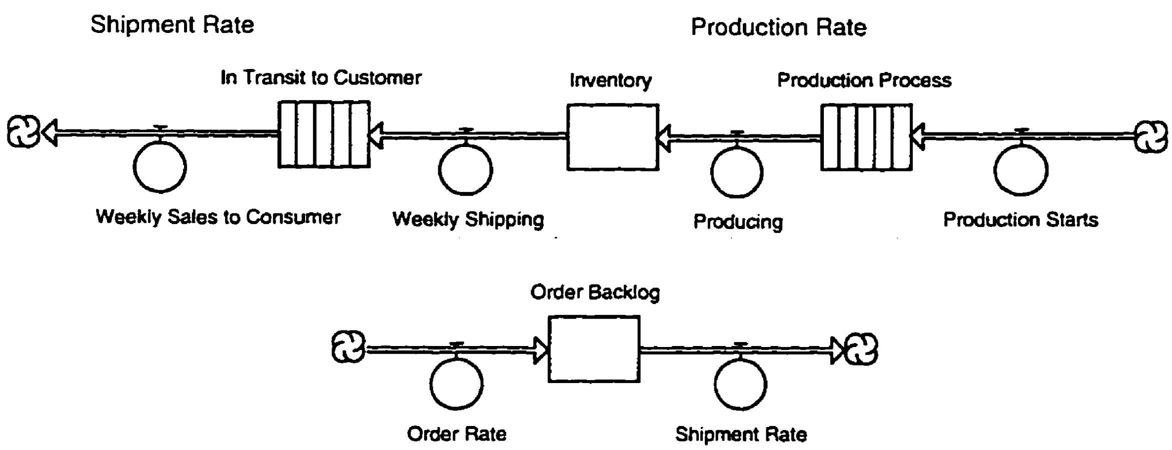


Figure 4.7 ithink® generated diagram of the major levels and rates for the model of a basic manufacturing organization

4.5 Basic Manufacturing Organization Models with Management Control Systems

Based on these common level and rate variables of the production function, we have constructed two manufacturing organization models, one with the mechanistic management control system and another one with the organic management control system. Organizational structure, the delay in decisions and actions, and the policies governing productions and inventories which constitute management control systems are implemented differently according to the conceptual model selected. Particularly, time delays which are one of the major determinants of behaviour of any

SD model (Wolstenholme, 1990), determine the dynamics of each mechanistic and organic management control systems.

4.5.1 Manufacturing Organization Model with the Mechanistic Management Control System

As presented in Section 4.2, the characteristics of the mechanistic management control system have been translated into the implementation model using the *ithink*® package as follows. *Marketing* and *Production* processes, as well as their duties within the *Management* function, are distinctively separated. Delays are used in communication between different functional areas, for example *Marketing* and *Production* processes to imply the divisions of labor. Delays are also embedded in the various report functions and a decision point --*VP Manufacturing* (where production decisions are made)-- in the model to mimic the actual dynamics of the organization. As well, multiple layers of *Management* imply organizational hierarchy in the model, and report functions between *Management* and *Production* functions emphasize the vertical communication in the model. Production policy (i.e. *Target Inventory*) and inventory policy (i.e. *1/k*) are set by the *President* in the *Management* function, and production decisions (i.e. *Production Rate*) of *VP Manufacturing* are transmitted down to the *Production* function. Figure 4.8 is an *ithink*® generated model diagram of the basic manufacturing organization model with the mechanistic management control system.

The model can be best described by going through an order cycle, the time between the order placement to order receipt. When *Marketing* (i.e. *Customer Order Received*) receives a *Customer Order*, this sets *Order Rate (OR)*, processes the order, and reports it (i.e. *Generate CO Report*) to the *VP Marketing* in the *Management* function with a time delay. Once *VP Marketing* gets the *Customer Order Report*, he or she then forwards this information to the *Production* function and the *VP Manufacturing*, with a time delay. The *Production* function reviews *Inventory(I)* to determine if there is sufficient quantity in *Inventory(I)* to meet the unfilled order (i.e. *Order Backlog: OB*) and the current period's customer demand (i.e. *OR*). If the *Production* function has enough in the *Inventory*, it then ships the amount demanded (i.e. *OB + OR* which becomes

Shipment Rate: SR) to the *Marketing* process, and the *Marketing* delivers the product (*SR*) to the *Customer* with a time delay. But, if the *Inventory* level is lower than *OB+OR* and greater than zero, then the *Production* function ships out the total number of units (*SR*) in *Inventory* to fulfill a part of unfilled order (*OB*) and/or current period's customer demand (*OR*). The undelivered quantity of order becomes the backlog order (*OB*) and the *Marketing* process attempts to meet this unfilled customer order as soon as the product becomes available.

Meanwhile, *VP Manufacturing* collects various status reports such as *Weekly Shipping, Inventory, Order Backlog*, and *Producing Reports* from the *Production* function (with a time delay) to make production decisions (i.e. *Production Rate: PR*) with the customer order information (*OR*); however, there are time delays in collecting the reports to make production decisions (*PR*). These delays in report function represent a traditional practice of the mechanistic management control system commonly known as "managing by results" (Johnson, 1995) where managers try to maintain or alter patterns in organizational activities based on "after-the-fact summaries of transactions" (Egol *et al.*, 1995). When all the relevant information are collected, *VP Manufacturing* makes production decisions according to the inventory policy (i.e. *Target Inventory: TI*) and production policy (i.e. *1/k*) set by the *President* and sends the production order to the *Production* function. Then the *Production* function produces the amount of a product specified and send it to *Inventory*.

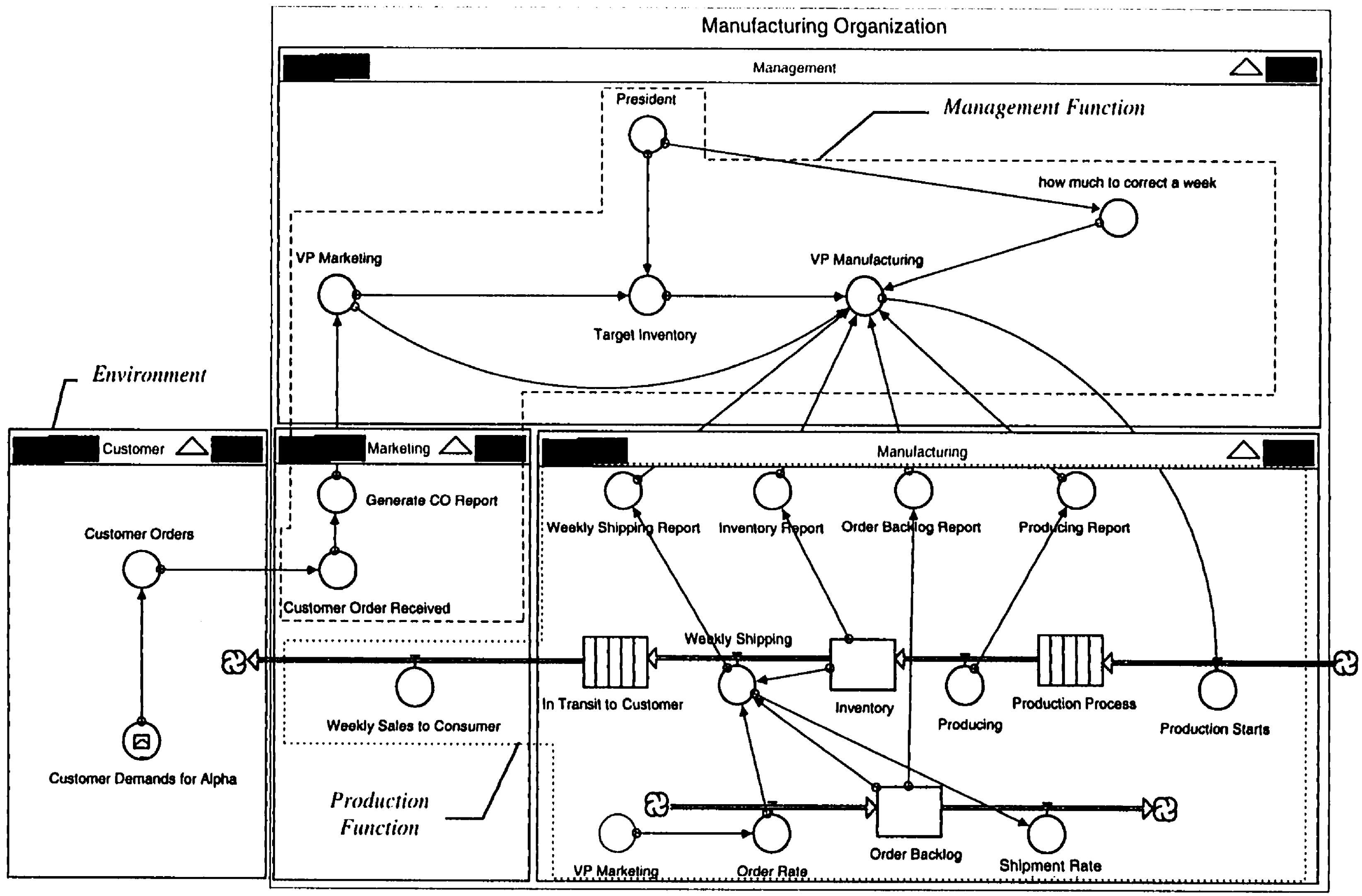


Figure 4.8 A Manufacturing System Model with the Mechanistic Management Control System

4.5.2. Manufacturing Organization Model with the Organic Management Control System
The characteristics of the organic management control system described in Section 4.2 have been translated into the implementation model using the *ithink*® as follows.

Marketing and *Production* processes, as well as duties within the *Management* function, are not clearly separated (i.e. time delays are not embedded in interactions between two process entities such as *Customer Order Received* and *Production Decision*). The *Management* function is organized in flat structure, while local decision making is maximized (thus there are no time delays in making decisions). For example, inventory policy (i.e. *Target Inventory*) and production policy (i.e. *1/k*) are decided at the *Production Decision* process entity in the model with the customer order information. As well, all relevant information to make production decisions become available to *Production Decision* process entity without time delays which represents high interaction among decentralized components. Figure 4.9 is an *ithink*® generated model diagram of the basic manufacturing organization model with the organic management control system.

Once again, the best view of the model is seen through following an order cycle. When the *Management* function (i.e. *Customer Order Received*) receives a *Customer Order*, which sets *Order Rate (OR)*, it immediately forwards this information to the *Production* function to determine if there is sufficient quantity in the *Inventory* to meet the customer demand (*OR*). If the *Production* function has sufficient *Inventory*, it then ships the amount demanded (i.e. *OB + OR* which becomes *Shipment Rate: SR*) to the *Customer* with a time delay. But, if the *Inventory* level is lower than *OB+OR* and greater than zero, then the *Production* function ships out the total number of units (*SR*) in the *Inventory* level. The undelivered quantity of order becomes the backlog order (*OB*) and the *Production* function attempts to meet this unfilled customer order as soon as the product becomes available. Meanwhile, the *Management* function (i.e. *Production Decision*) makes production decisions (*PR*) with the customer order information (*OR*) while working closely with or working at the production line (i.e. the *Production* function).

High interaction among decentralized components in the manufacturing system, emphasis on local decision making, and horizontal communication without delays allow this manufacturing system with the organic management control system to be able to practice something we refer to as "managing in real time." "Managing in real time" allows employees and managers to make decisions based on current transactions rather than after-the-fact summaries of transactions. In other words, "managing in real time" reduces time delays in information flows between an entity which makes a decision and another entity which executes the decision by empowering one entity to perform both tasks of making and executing a decision.

The specific values of parameters used in the two models are discussed in the subsequent section.

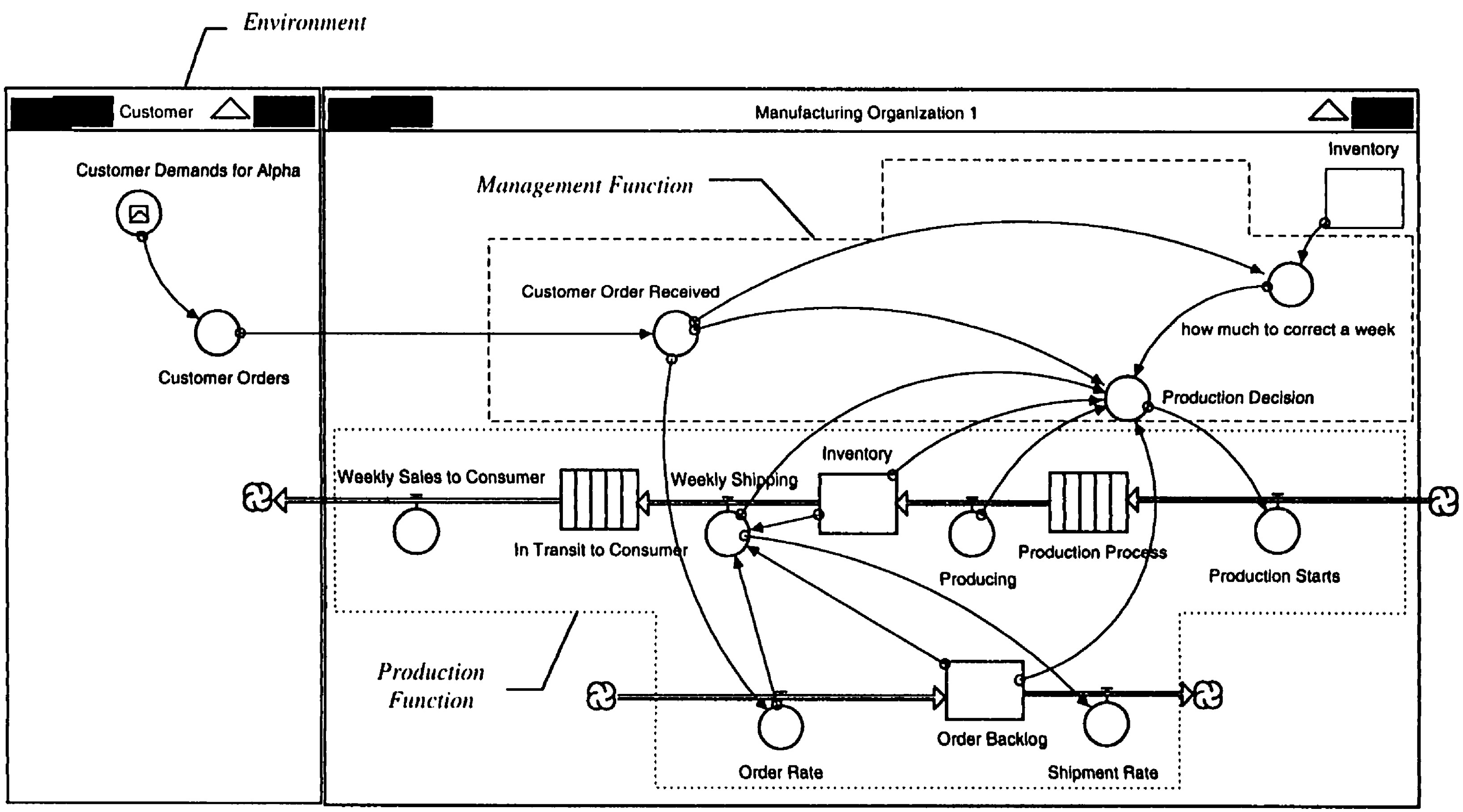


Figure 4.9 A manufacturing system model with the organic management control system

4.6 Parameters in the Simulation Model

Based on Forrester's original production-distribution model (Forrester, 1961; Sterman, 1989; Senge, 1990), the major level and flow rate variables of the manufacturing function of both models have been set with the following values in Table 4.2.

Level and Rate variables	*Names in ithink®*	*Initial Value*
Order Rate (*OR*)	*Customer Orders*	4,000 units/week
Production Rate (*PR*)	*Production Process*	4,000 units/week
Shipment Rate of Inventory (*SR*)	*In Transit to Customer*	4,000 units/week
Shipment Rate of Order Backlog (*SR*)	*Filled Order*	4,000 units/week
Inventory Level (*I*)	*Inventory*	12,000 units
Order Backlog Level (*OB*)	*Order Backlog*	0 unit
Desired Target Inventory (*TI*)	*Target Inventory*	12,000 units

Table 4.2 Initial values for level and rate variables

Process	Information Input(s) From	Information Output(s) To	Time Delay (in weeks)
Customer_Order (OR)	***Customer_Demand (OR): Source***	*Customer_Order_Received (OR)*	*0*
Customer_Order_Received	*Customer_ Order (OR)*	*Generate_CO_Report (OR)*	*0*
Generate_CO_Report (OR)	*Customer_Order_Received (OR)*	*VP_Marketing (OR)*	*dp*
VP_Marketing (OR)	*Generate_CO_Report (OR)*	*Target_Inventory (TI)* *VP_Manufacturing*	*0* *0*
President(k, m): Source	*n/a*	*Target_Inventory(TI)*	*0*
Target_Inventory(TI)	*VP_Marketing (OR),* ***President(m) : Source***	*VP_Manufacturing (PR)*	*0*
Weekly_Shipping_Report (SR)	***Order_Backlog (OB): Source*** ***Order_Rate (OR): Source***	*VP_Manufacturing (PR)*	*2•dp*
Inventory_Report (I)	***Inventory(I): Source***	*VP_Manufacturing (PR)*	*2•dp*
Producing_Report (PR)	***Producing (PR): Source***	*VP_Manufacturing (PR)*	*2•dp*
Order_Backlog_Report (OB)	***Order_Backlog (OB): Source***	*VP_Manufacturing (PR)*	*2•dp*
how_much_to_correct_a_week(k)	***President(k): Source***	*VP_Manufacturing (PR)*	0
VP_Manufacturing (PR)	*VP_Marketing (OR),* *Target_Inventory (TI),* *Weekly_Shipping_Report (SR),* *Inventory_Report (I),* *Producing_Report (PR),* *Order_Backlog_Report(OB),* *how_much_to_correct_a_week (k)*	***Production_Starts (PR): Sink***	*dp*

Note:
•*dp* is a global parameter in the model which manipulates time delays in the model.
•*Customer_Order* is an external process which is a major source of information and initiates an order cycle.
•***Source*** indicates the origin of information external to the management control system (except the *President*).
•***Sink*** indicates the destination of information external to the management control system.
•Content of information is indicated within parentheses.
•*m* from *President* is a multiplier which determines the *Target Inventory (TI)* level.

Table 4.3 Parameters of various processes representing mechanistic management control system

Process	Information Input(s) From	Information Output(s) To	Time Delay (in weeks)
Customer_Order (OR)	***Customer_Demand (OR): Source***	*Customer_Order_Received (OR)*	*0*
Customer_Order_Received (OR)	*Customer_ Order (OR)*	*Order_Rate (OR)*	*0*
Weekly_Shipping (SR): Source	*n/a*	*Production_Decision (PR)*	*0*
Inventory (I): Source	*n/a*	*Production_Decision (PR)* *how_much_to_correct_a_week (k)*	*0*
Producing (PR): Source	*n/a*	*Production_Decision (PR)*	*0*
Order_Backlog: Source	*n/a*	*Production_Decision(PR)*	*0*
how_much_to_correct_a_week (k)	***Inventory (I): Source***	*Production_Decision(PR)*	*0*
Production_Decision (PR)	*Customer_Order_Received (OR)* *Weekly_Shipping (SR)* *Inventory (I)* *Producing (PR)* *Order_Backlog (OB)* *how_much_to_correct_a_week (k)*	***Production_Starts (PR): Sink***	*dp*

Note:
- *dp* is a global parameter in the model which manipulates time delays in the model.
- *Customer_Order* is an external process which is a major source of information and initiates an order cycle.
- ***Source*** indicates the origin of information external to the management control system.
- ***Sink*** indicates the destination of information external to the management control system.
- Content of information is indicated within parentheses.

Table 4.4 Parameters of various processes representing organic management control system

Additionally, two sets of parameters of various processes (i.e. circle entities in Figures 4.8 and 4.9) which define two management control systems are presented separately in Table 4.3 and 4.4. These parameters set time delays within each system to simulate the dynamics of each management control system. In Appendix 1 and 2 we present detailed *ithink*® generated model documentation for each model respectively.

4.7 Validation Model

Since Forrester introduced the production-distribution model in 1961, validation of systems dynamics simulation models has been often the subject of close scrutiny (Ansoff and Slevin, 1968; Legasto and Maciariello, 1980; Forrester and Senge, 1980; Sterman, 1984; Barlas, 1989; Barlas and Carpenter, 1990). According to Law and Kelton (Ch 5, 1991), model validation "is concerned with determining whether the conceptual simulation model is an accurate representation of the system under study." Traditionally, model validation is associated with formal, objective, quantitative validation tests such as statistical measures of goodness-of-fit test and system dynamics model builders are often criticized for their reluctance to use such formal measures for model validation (Sterman, 1984; Barlas and Carpenter, 1990).

But, two paradigms exist regarding model validation. The first one is a formal, objective, and quantitative approach and the second one is a social, judgmental, and qualitative approach (Barlas and Carpenter, 1990). Each paradigm stems from fundamentally different philosophical views of the world. The first formal approach assumes that a "valid" model is "an objective and absolute representation of the real system" (Barlas and Carpenter, 1990). The valid model has to be very close to true representation of the real world or else its usefulness is reduced. Therefore, it is critical to have a formal way to measure accuracy of the model rather than its practical use. On the other hand, the second model validation approach assumes a valid model to be "only one of many possible ways of describing a real situation" (Barlas and Carpenter, 1990). The model is assumed to be valid as long as the model is proved to be useful to users of the model. Thus it is important for a model builder to be able to build confidence in model's usefulness and to transfer confidence to people not directly involved in model construction (Forrester and Senge, 1980). However, since we do not have actual users of the simulation model, we have asked experts[1] in the field of manufacturing and management control systems to evaluate and validate the model.

We subscribe to the second approach of a model validation for the following reason: We do not intend to build an exact representation of a real world manufacturing organization, but "microworlds" that are "specially designed to highlight (and make accessible) particular concepts and particular ways of thinking" (Resnick, 1994). Since we are trying to explain the relationship between management control systems and performance of manufacturing systems, we intend to build a generic manufacturing model which modification can be made easily if needed for a specific simulation.

[1] Prof. Jewekes, E. M. in the Department of Management Sciences, Prof. Russell, G.W. in School of Accountancy, and Prof. Dilts, D.M. in the Department of Management Sciences, University of Waterloo were asked to evaluate the basic manufacturing models.

Forrester and Senge (1980) summarizes a number of tests that can help SD model builders increase confidence on SD models they build (see Table 4.5, Note: The tests in the shaded cells are core ones according to Forrester and Senge). Before we asked our experts to validate the model, we performed each test with both basic manufacturing organization models and the results are summarized in the Appendix 3 and 4. With these two validated models, we built different types of extended enterprise models in the following section.

Tests For Building Confidence in System Dynamics Models	
Test of model structure	
Structure Verification	*Is the model structure consistent with relevant descriptive knowledge of the system?*
Parameter (constant) Verification	*Are the parameters consistent with relevant descriptive (and numerical, when available) knowledge of the system?*
Extreme Conditions	*Does each equation make sense even when its inputs take on extreme values?*
Boundary Adequacy (Structure)	*Are the important concepts for addressing the problem endogenous to the model?*
Dimensional Consistency	*Is each equation dimensionally consistent without the use of parameter having no real-world counterpart?*
Test of model behaviour	
Behavior Reproduction	*Does the model generate the symptoms of the problem, behaviour modes, phasing, frequencies, and other characteristics of the behaviour of the real system?*
Behavior Prediction	*Does the model generate qualitatively correct patterns of future behavior?*
Behaviour Anomaly	*Does anomalous behaviour arise if an assumption of the model is deleted?*
Family Member	*Can the model reproduce the behaviour of other examples of systems in the same class as the model (e.g. can an urban model generate the behaviour of New York, Dallas, Carson City, and Calcutta when parametrised for each)?*
Surprise Behaviour	*Does the model point to the existence of a previously unrecognized mode of behaviour in the real system?*
Extreme Policy	*Does the model behave properly when subjected to extreme policies or test inputs?*
Boundary Adequacy (Behaviour)	*Is the behaviour of the model sensitive to the addition or alteration of structure to represent plausible alternative theories?*
Behaviour Sensitivity	*Is the behaviour of the model sensitive to plausible variations in parameter?*
Statistical Character	*Does the output of the model have the same statistical character as the 'output' of the real system?*
Tests of policy implications	
System Improvement	*Is the performance of the real system improved through use of the model?*
Changed-Behaviour Prediction	*Does the model correctly describe the results of a new policy?*
Boundary Adequacy (Policy)	*Are the policy recommendations sensitive to the addition or alteration of structure to represent plausible alternative theories?*
Policy Sensitivity	*Are the policy recommendations sensitive to plausible variations in parameters?*

Adopted from Forrester and Senge (1980) and Sterman (1984)

Table 4.5. Tests for building confidence in system dynamics models

4.8 Implementation Models of Extended Manufacturing Organizations

Based on the three structures of extended enterprise models discussed in Section 2.3 (Figures 2.3, 2.4, and 2.5) and the basic manufacturing organization framework (Figure 4.1 in Section 4.2), we have constructed the following implementation models of extended enterprises using *ithink*®. With these three models, a total of 24 implementation models of extended enterprises were constructed with different types of interactions of management control systems. *ithink*® generated model diagrams for 24 extended enterprises model are presented in Appendix 5.

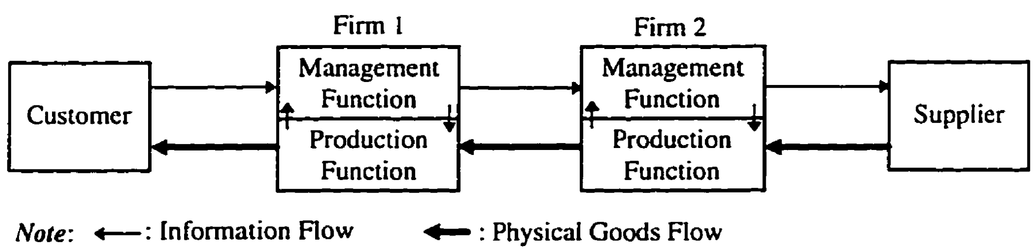


Figure 4.10 An Extended Enterprise performing unpartitionable sequential tasks

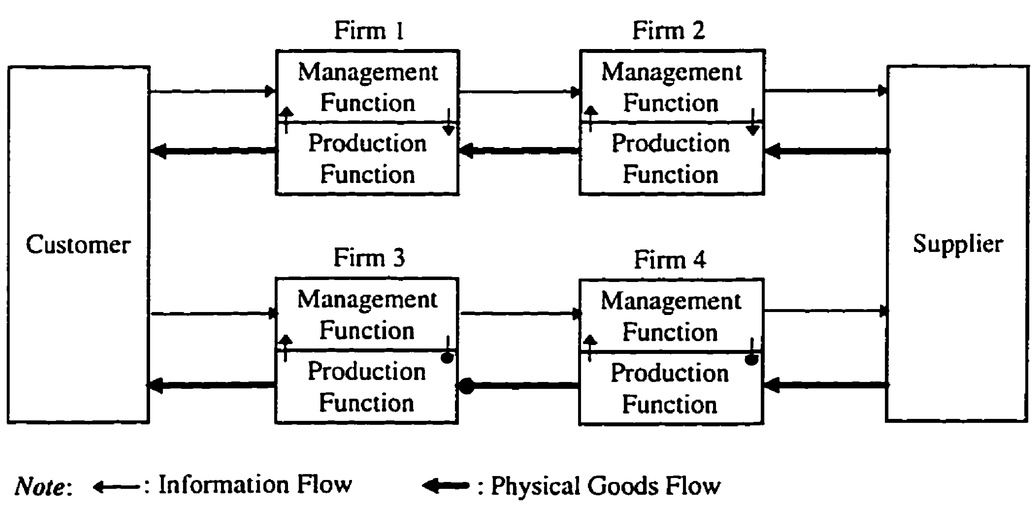


Figure 4.11 An Extended Enterprise performing partitionable sequential tasks

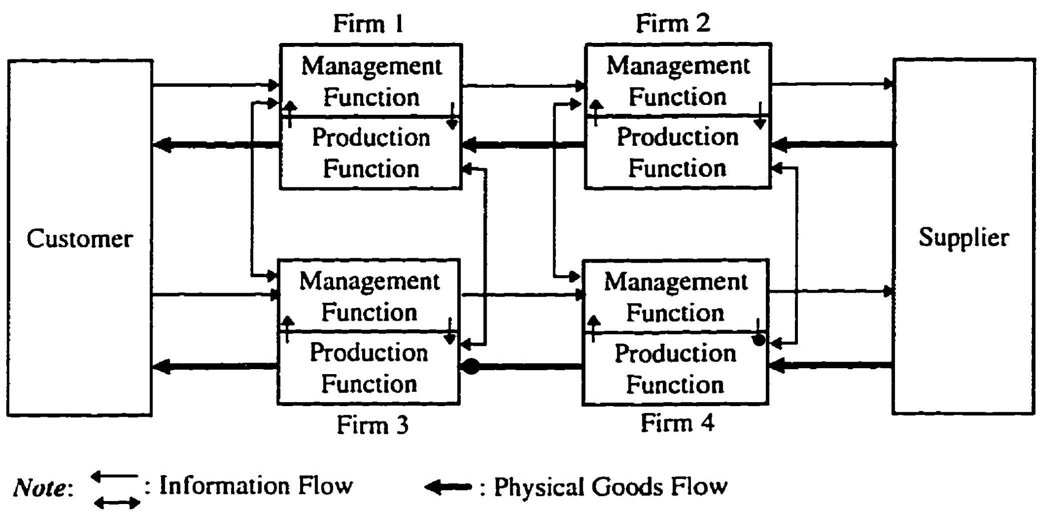


Figure 4.12 An Extended Enterprise performing reciprocal tasks

However, in order to construct 24 extended enterprise models with two basic manufacturing organization models, connectors were created between two individual manufacturing organizations within an extended enterprise using the level variable construct (i.e. rectangles in *ithink*® diagram). For the extended enterprise models structured to perform unpartitionable sequential tasks, *en route to 1* (between Firm 1 and Firm 2) and *en route to* 2 (between Firm 2 and Supplier) which represent the connectors were created. Furthermore, for the extended enterprise models structured to perform partitionable sequential and reciprocal tasks, *en route to 1* (between Firm 1 and Firm 2), *en route to 3* (between Firm 3 and firm 4), and *en route to 2 and 4* (between Firm 2 and Firm 4, and Supplier) were constructed as the connectors. The connectors do not represent actual level variables or affect behavior of individual manufacturing organization models, but to link two individual manufacturing organization models through two conveyors (i.e. rectangles with vertical lines in *ithink*® diagram), the use of level variable construct is inevitable.

Moreover, for extended enterprise models performing reciprocal tasks which are more difficult and costly to coordinate (Thompson, 1967), *coordination effect* process entities were set up between two supply chains (i.e. between Firm 1 and Firm 3, and between Firm 2 and Firm 4 in

Figure 4.12). *Coordination effect*, which is expressed in terms of additional time delay, represents higher costs of reciprocal tasks coordination than either unpartitionable or partitionable sequential tasks coordination, and is determined by the following equation:

$$[N * (N-1)/2] * \{1/[TN * (TN-1)/2]\} * (dp/0.25), \qquad N \leq TN$$

where	*N*	*= a number of partners in reciprocal tasks coordination*
	TN	*=Total number of manufacturing firms in an Extended Enterprise*
	dp	*= time delay parameter*

As the number of partners (N) working on reciprocal tasks grows, the coordination cost increases by $N * (N-1)/2$ (Brooks, 1975). The term $N * (N-1)/2$, is first multiplied by $\{1/[TN * (TN-1)/2]\}$ to normalize the result between 0 and 1. Then the result is again multiplied by $(dp/0.25)$ to express the result in terms of time. The denominator 0.25 is used since the two basic manufacturing organization models are built with *dp* of 0.25, and are modified time-related terms in proportion of 0.25. Therefore, two *coordination effect* process entities were set up between Firm 1 and Firm 3, and also between Firm 2 and Firm 4 in Figure 4.12 to represent one level of coordination effort at the *Management* function and another level of coordination effort at the *Production* function.

In addition, as the number of working partners (N) increases, the amount of individual partner's work decreases by some amount (Brooks, 1975). It is assumed that the amount of work is decreased by $1/N$ (where $N \leq TN$) and this reduction effect in the amount of work due to cooperation is implemented in the extended enterprise models. For example, if a customer order rate in week 2 is 4,000 units, an extended enterprise with one supply chain as in Figure 4.10, the single supply chain must produce all 4,000 units on its own. However, the other extended enterprise with two supply chains as in Figure 4.11 or 4.12, each supply chain produces 2,000 units to satisfy the customer demand of 4,000 units (i.e.*Customer Order (OR)* is divided by the number of supply chains).

So far we have discussed constructing implementation models of 24 extended enterprises based on two basic manufacturing organization models. However, the implementation models of extended enterprise have two external processes (or entities), that are the Customer and Supplier; therefore, before proceeding to the next section, Customer and Supplier entities will be briefly described.

Customer

Customer, which initiates order cycles of an extended enterprise and represents external environments, is presented as in Figure 4.13. *Customer Orders (OR)* are determined based on the *Customer Demands* over all periods and is set at a constant base level (*CBL*). By using the *ithink*® built-in random number function, fluctuation of *Customer Orders (CO)* in each period is simulated using the *Random Number Generator* and generating random *Customer Orders (CO)* is further discussed in section 4.10.

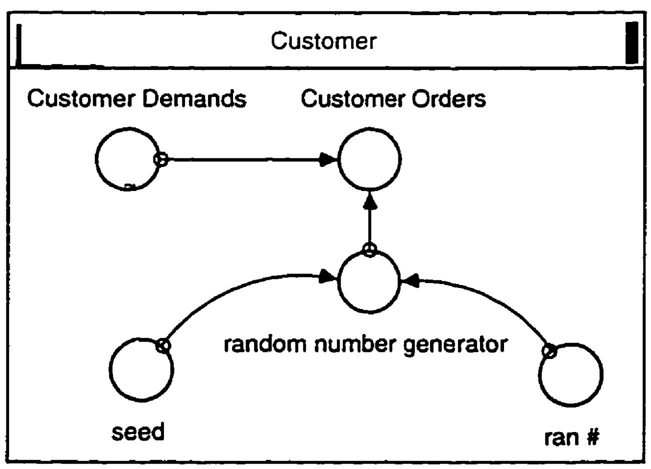
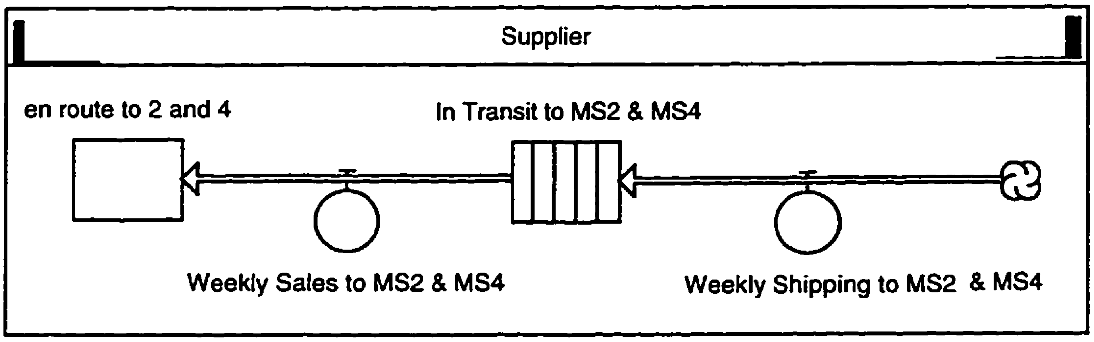


Figure 4.13 *ithink*® generated diagram of *Customer*

Supplier

Supplier is assumed to be able to supply any quantity of material demanded by an extended enterprise and it takes a fixed 0.25 weeks to deliver the material to the extended enterprise. Therefore, potential disturbance or variability coming from *Supplier* are eliminated in this research. Figure 4.14 presents the *ithink*® generated diagram of *Supplier*.



Note: MS2 and MS4 stands for Manufacturing System (Organization) 2 and 4

Figure 4.14. *ithink*® generated diagram of *Supplier*

4.9 Extended Enterprise Models Validation

The qualitative verification of the model validity of individual 24 implementation models of extended enterprises was performed by answering a part of the set of questions introduced by Forrester and Senge (1980). Especially, behavior of each model was closely tested with respect to behavior reproduction and behavior under extreme conditions. For behavior reproduction test, the original Beer Distribution Game scenario was played to see if the model exhibited any unusual behavior. For model behavior test under extreme conditions, each simulation model was run with 1) a constant customer demand of 4,000 units/week over 1,000 weeks and 2) a sudden, one time perturbation of customer demand to 500,000 units/week from a constant customer demand level of 4,000 units/week in fourth week of the simulation over 108 weeks.

All 24 models passed the behavior reproduction test and the second case for the extreme condition tests. However, some models of extended enterprises, RMMMM, RMOMO, RMMOO, RMMMO, SMMMM, SMOMO, SMMOO, and SMMMO exhibited an abnormal behavior in their inventory level with the first case of the extreme condition test. With the constant customer demand of 4,000 units/week, inventory level of each model was expected to be constant at 12,000 units over 1,000 weeks, since the initial production rate exactly matched the 4,000 units of customer demand. However, the extended enterprise models listed above exhibited a sudden, one-time disturbance in the inventory level in the middle of its simulation run over 1,000 weeks. This unusual perturbation in inventory level was investigated.

The problem occurred at the connector between manufacturing units and the supplier with extended enterprises structured to perform either partitionable sequential or reciprocal tasks. An initial value of a level variable must be set for every level variable entities in *ithink*®, whether they are actual level variables such as *Inventory* or level variables like the connector, and the initial value of 1,000 caused the perturbation problem in the models mentioned above. Thus, using sensitivity analysis, an initial value of 250 units for the connector between manufacturing units and the supplier was determined to solve the perturbation problem in inventory level. Once corrections were made in 24 models with this new value for the connector, behavior of models under extreme conditions with first scenario as well as the other tests described above were re-tested and all 24 models passed.

4.10 Summary

The goal of Chapter 4 was to present implementation models developed for this research. Section 4.2 described the conceptual model of the basic manufacturing organization. Section 4.3 outlined the study methodology. Section 4.4 discussed the basic concepts and structures of system dynamics model, and based on the discussion, the *Production* function of the basic manufacturing organization model was constructed. Then, Section 4.5 the *Management* function of the basic manufacturing organization model was added to the model constructed in the previous section. Sections 4.6 described initial parameters used in the model. Section 4.7 discussed the issues of system dynamics model validation and presented the results of the basic manufacturing models validation. Finally, Sections 4.8 to 4.9, the implementation models of extended enterprises were constructed using the two basic manufacturing system models and the results of the validation tests for the extended enterprise models were presented.

The next chapter will present the results and analysis of hypotheses testing as well as a *post hoc* multiple comparisons using Scheffé test to identify effective (or ineffective) frameworks of management control systems for an extended enterprise operating within a specific combination of contingent factors.

CHAPTER FIVE

Results and Analysis

5.1 Introduction

In Chapters 3 and 4, we described an experimental design and an experimental setting for this research. The experiment setting evolved however, with two experiments performed and analyzed prior to designing the final experiment. Furthermore, these two experiments served as additional validation steps for the extended enterprise models. This chapter contains five additional sections. Sections 5.2 describes dependent variables employed across all three experiments and how they were measured. Sections 5.3 and 5.4 present experiment settings for first two experiments, results and analysis of the hypotheses tests, and changes in experiment settings for the subsequent experiment. Section 5.5 summarizes the final experiment setting and presents the results and analysis of hypotheses testing.

Analysis of variance (ANOVA) was employed for quantitative statistical analyses. Together with the ANOVA results, a *post hoc* multiple comparisons using Scheffé test was completed to identify effective (or ineffective) frameworks of management control systems for an extended enterprise operating within a specific combination of contingent factors. Unless otherwise specified, all quantitative statistical analyses were performed using Statistical Package for the Social Sciences (SPSS), version 6.1 for Microsoft Windows. ANOVA tests used $\alpha = 0.001$ to determine statistical significance and Scheffé tests employed $\alpha = 0.05$.

5.2 Dependent Variables

The dependent variables employed across all three experiment settings were: (1) the sum of inventory holding costs and stockout costs called financial measure (*FM*), (2) standard deviation of order delivery time (*OSTDV*), and (3) standard deviation of manufacturing cycle time (*PSTDV*).

Financial measure (i.e. *FM*), the sum of inventory holding costs and stockout costs in each period over total number of periods (i.e. *T*), was measured with the following equation adopted from the Beer Distribution Game (Sterman, 1989):

$$FM = \sum_{n=1}^{N} \sum_{t=1}^{T} [(I_t * C_I) + (OB_t * C_B)]$$

where
FM = *Financial Measure*
I_t = *Inventory*
OB_t = *Order Backlog*
N = *Total number of individual manufacturing units within an extended enterprise*
T = *Total number of periods*
C_I = *cost of Inventory/week*
C_B = *cost of Backlog/week*

The other two measures of delivery (i.e. *OSTDV*) and production process (i.e. *PSTDV*) were measured by using an *ithink*® built-in cycle time function called *CTSTDDEV*. The *CTSTDDEV* function returns the per batch standard deviation in cycle time, since the start of the simulation run, associated with time-stamped material moving through the flow (High Performance Systems, Inc., 1996).

When an extended enterprise receives a customer order (*i.e. OR*), the customer order is time-stamped, and when the shipment for the order is scheduled for delivery, the order delivery cycle time for the specific order is terminated (Note: Actual physical shipment of products from an extended enterprise to the customer takes 0.25 weeks, however due to the limitation of *ithink*®, this physical delivery time is not included in the order cycle time.). Therefore, the *CTSTDDEV* function for the measure of delivery (*OSTDV*) returns the standard deviation of order delivery cycle times for all orders in *T*. *OSTDV* was measured in the manufacturing unit working nearest the customer in each supply chain. When there were two supply chains in an extended enterprise as in Figures 4.11 and 4.12 (in Chapter 4), the worse result of the two was taken as the delivery measure (*OSTDV*) of the extended enterprise as the following:

$$OSTDV_{EX} = \begin{cases} MAX(OSTDV_1, OSTDV_2) & if\,(NSC = 2) \\ OSTDV_{NSC} & if\,(NSC = 1) \end{cases}$$

where $OSTDV_{EX}$ = *Measure of Delivery of the Extended Enterprise*
$OSTDV_1$ = *Measure of Delivery of Supply Chain 1*
$OSTDV_2$ = *Measure of Delivery of Supply Chain 2*
NSC = *Number of Supply Chain(s) in an Extended Enterprise*

Similarly, the *CTSTDDEV* function for the manufacturing process variability measure (*PSTDV*) returns the standard deviation of manufacturing cycle times in *T*, associated with material moving through the manufacturing flow between material receipt from the supplier to product shipment to the customer. *PSTDV* was measured in each supply chain and when there were two supply chains in an extended enterprise as in Figures 4.11 and 4.12 (in Chapter 4), again the worse result of the two was taken as the production process measure (*PSTDV*) of the extended enterprise as the following equation.

$$PSTDV_{EX} = \begin{cases} MAX(PSTDV_1, PSTDV_2) & if\,(NSC = 2) \\ PSTDV_{NSC} & if\,(NSC= 1) \end{cases}$$

where $PSTDV_{EX}$ = *Measure of Production Process of the Extended Enterprise*
$PSTDV_1$ = *Measure of Delivery of Supply Chain 1*
$PSTDV_2$ = *Measure of Delivery of Supply Chain 2*
NSC = *Number of Supply Chain(s) in an Extended Enterprise*

5.3 First Experiment

The 48 experimental factor settings presented in Section 3.3 (see Table 3.2) were used in this experiment. Without knowing the number of data sets of each 48 factor settings required to produce the probability that a statistical test would result in statistical significance, we used a sample size of 100 for this first exploratory experiment. Power analysis was performed with the results of this experiment to calculate statistical power and determine sample size for subsequent experiments. The results of the power test is presented in Section 5.3.3.

Number of factor settings	48
Number of replication per factor setting	100
Total number of cases	4,800
Total number of periods (*T*)	54 weeks
Total number of individual manufacturing units (*N*)	2 or 4
Customer Demand	
Base Level (*CBL*)	4,000 units/week
Environments (2 *levels*)	
Stable	-100% to +210% of base
Dynamic	-100% to +600% of base
Delay Parameter (*dp*)	0.25 weeks
Management Cycle Time	
Mechanistic	0.75 weeks
Organic	0.25 weeks
Manufacturing cycle Time	
Mechanistic	0.50 weeks
Organic	0.50 weeks
Reaction Rate (*1/k*)	1/1.5
Cost of Inventory/week (C_I)	\$0.50/week
Cost of Backlog/week (C_B)	\$1.00/week

Table 5.1 Summary of the first experiment settings

Each experiment was performed over a period of 54 simulated weeks using 7 days work week. Input variable of each simulation run --customer order in each week-- was randomly generated using the *ithink*® built-in random number function which generates a uniformly distributed stream of random numbers. -100% to +210% fluctuation of customer demand base level (*CBL:* 4,000 units/week) was assumed to simulate stable environments, while -100% to +600% of *CBL* was assumed to simulate dynamic environments. In addition, the original setting, 0.25 weeks was used as the artificial delay parameter (*dp*), which is a global parameter in the model which manipulates time delays in the model, and the reaction rate (*1/k*), 1/1.5 was employed. Table 5.1 summarizes the first experiment settings.

Summary results of ANOVA tests for these settings are presented in Table 5.2.

	Dependent Variables	Independent Variables			
		ENV H_1 *p-value*	INTER H_2 *p-value*	STRUCT H_3 *p-value*	ENV x INTER H_4 *p-value*
First Experiment	*FM*	0.000	**0.002**	**0.003**	**0.082**
	OSTDV	0.000	0.000	0.000	0.000
	PSTDV	0.000	0.000	0.000	0.000

Note: •*FM* stands for financial measure.
•*OSTDV* represents deviation of order delivery time.
•*PSTDV* represents standard deviation of manufacturing cycle time.
•ENV stands for Environments.
•INTER represents interactions of management control systems.
•STRUCT stands for structure.
•ENV x INTER denotes interactions between ENV and INTER.

Table 5.2 Summary results of ANOVA tests of the first experiment

5.3.1 Hypotheses Testing

The interactions of three contingent factors were examined using a test for interaction between two factors, environments and types of interactions of management control systems (i.e. Hypothesis IV). A test for an interaction containing types of interactions of management control systems and structures of extended enterprises together cannot be processed since both originated from a singular matrix. Therefore, external environments and types of interactions of management control systems were used to test an interaction between these two contingent factors of interest within each structure of extended enterprises. When an interaction between the two variables is identified, it means that organizational performance is not simply determined by external environments or by interactions of management control systems, but by the particular combination of the factor levels of the variables, and supports our fundamental premises of this research. However if significant interactions are not present, effects on organizational performance of the individual variables should be further investigated using the hypotheses I, II, and III.

Hypothesis IV argued that there would be no significant interaction among environments in which extended enterprises operate, interactions of the mechanistic and/or organic management control systems in extended enterprises, and structures of extended enterprises. As Table 5.2 reports, hypothesis IV is not rejected for financial dimensions of organizational performance, whereas it is rejected with the measures of delivery and production flow.

Hypothesis I argued that different types of environments, which are stable and dynamic, would have no effect on the performance of an extended enterprise. The results of ANOVAs indicate that hypothesis I is rejected for all three dimensions of performance as presented in Table 5.2. In other words, the results of experiments suggest that changes in environmental conditions have statistically significant effects on organizational performance of an extended enterprise.

Hypothesis II examined if alternative choices in types of interactions of the mechanistic and/or organic management control systems in extended enterprises would not be different in the performance of an extended enterprise. As the results presented in Table 5.2 indicate, hypothesis II is not rejected for the financial dimension of organizational performance (*FM*) contrary to the prediction, whereas it is rejected with the measures of delivery (*OSTDV*) and production flow (*PSTDV*).

Hypothesis III argued that different structures of extended enterprises have no effect on the performance of an extended enterprise. The hypothesis III test again results in conflicting results depending on performance measures (see Table 5.2). Contrary to predictions, the financial measure indicates that structures of an extended enterprises have no statistical effect on the performance of an extended enterprise, while the measures of delivery and production flow suggested that different structures of extended enterprises based on the nature of tasks interdependence had an effect on the performance of an extended enterprise.

Hypothesis IV, and subsequently hypotheses II and III are not rejected for financial dimensions of organizational performance contrary to the predictions, thus these results lead into further investigation of the *FM* and this discussion will be presented in Section 5.3.3.

5.3.2 *Post Hoc* Analyses

One-way analysis of variance (ANOVA) with *post hoc* Scheffé multiple comparison tests was employed to identify effective (or ineffective) frameworks of management control systems for an extended enterprise operating within a particular combination of the contingent factors. The mean values of the three measures of performance on 48 factor settings are presented in Table 5.3. Within each combination of the three contingent factors, management control system frameworks are separated into groups to show the relative effectiveness of each group of management control systems frameworks when statistical significance among frameworks are found (Note: n/a in the Group column, denoted by "Grp" in Table 5.3 indicates that no two frameworks are significantly different statistically). Each group is denoted by a letter and the ascending order of alphabet represents the relative effectiveness of the groups of management control system frameworks. For example, the group "a" always represents the most effective group of frameworks and the group "b" represents a less effective group than the group "a," the group "c" represents a less effective group than the group "b," etc. Apart from statistical significance, a framework which results in the best mean value (i.e. the smallest mean value) is bold-faced, while another framework which results in the worst mean value (i.e. the largest mean value) is italicized. Lastly, a hyphen (i.e. "-") for an F statistics denotes a zero variance among different frameworks because they all result in an identical organizational performance.

As presented in Table 5.3, the measure of costs (*FM*) favors the organic-then-mechanistic (OM) management control systems framework with extended enterprises structured to perform the unpartitionable sequential tasks. On the other hand, with the partitionable sequential tasks, the management control systems framework of all organic management control systems (i.e. SOOOO) resulted in the largest costs (i.e. *FM*) across stable and dynamic environments. However, with the reciprocal tasks, no statistical significance was found on the *FM* among different frameworks of management control systems.

First Experiment												
Dependent Var.	FM				OSTDV				PSTDV			
Environment	Stable		Dynamic		Stable		Dynamic		Stable		Dynamic	
	Mean	Grp	Mean	Grp	Mean	Grp	Mean	Grp	Mean	Grp	Mean	Grp
Unpartitionable sequential tasks	*F = 0.0000*		*F=0.0003*		*F=0.0085*		*F=0.0004*		*F=0.0000*		*F=0.0000*	
2MM	922,177	b	2,351,722	b	*.0029*	*b*	*.1813*	*b*	*1.57*	*b*	*5.63*	*b*
2MO	886,599	a	2,290,778	b	.0008	a	.1556	a	1.12	a	4.67	b
2OM	**831,467**	**a**	**2,069,843**	**a**	**.0000**	**a**	.1565	a	**0.97**	**a**	**4.09**	**a**
2OO	*937,361*	*b*	*2,367,749*	*b*	**.0000**	a	**.1317**	**a**	1.19	a	4.51	a
Partitionable sequential tasks	*F=0.0000*		*F=0.0000*		-		*F=0.0000*		*F=0.0000*		*F=0.0000*	
SMMMM	954,105	a	2,311,528	a	.0000	n/a	*.0595*	*c*	*1.10*	*b*	*3.86*	*c*
SMMMO	960,494	a	2,326,735	a	.0000		.0469	b	0.96	a	3.52	a
SMMOM	930,565	a	2,254,946	a	.0000		.0358	a	0.93	a	3.37	a
SMMOO	1,007,279	a	2,444,036	a	.0000		.0328	a	1.00	a	3.62	b
SMOMO	966,882	a	2,266,370	a	.0000		.0318	a	0.82	a	3.05	a
SMOOM	936,953	a	2,270,152	a	.0000		.0231	a	0.79	a	3.03	a
SOMOM	**907,025**	**a**	**2,198.363**	**a**	.0000		.0117	a	**0.76**	**a**	**2.88**	**a**
SOOMO	1,025,128	b	2,489,370	a	.0000		.0273	a	0.88	a	3.38	a
SOOOM	983,739	a	2,387,454	a	.0000		.0088	a	0.83	a	3.13	a
SOOOO	*1,060,452*	*c*	*2,576,544*	*b*	.0000		**.0059**	**a**	0.90	a	3.38	a
Reciprocal tasks	*F=0.0041*		*F=0.0267*		*F=0.2950*		*F=0.0000*		*F=0.0000*		*F=0.0000*	
RMMMM	983,810	n/a	2,402,365	n/a	.0016	n/a	*.0835*	*b*	*1.47*	*d*	*4.44*	*b*
RMMMO	991,138		2,340,944		.0017		.0744	a	1.25	c	3.94	a
RMMOM	961,674		2,343,016		.0009		.0592	a	1.23	b	3.90	a
RMMOO	1,015,183		2,400,229		.0009		.0574	a	1.21	a	3.91	a
RMOMO	998,467		2,436,555		.0017		.0704	a	1.03	a	3.74	a
RMOOM	969,003		2,360,111		.0008		.0531	a	1.01	a	3.55	a
ROMOM	**939,539**		**2,283,667**		.0000		.0356	a	0.99	a	**3.35**	**a**
ROOMO	1,021,237		2,501,033		.0009		.0583	a	0.98	a	3.78	a
ROOOM	993,048		2,420,166		.0000		.0347	a	0.97	a	3.53	a
ROOOO	*1,046,556*		*2,556,666*		.0000		**.0339**	**a**	**0.94**	**a**	3.70	a

Table 5.3. Results of the Scheffé tests: First Experiment

Overall, investigating the mean values of the *FM* without statistical testing for significance, the management control systems frameworks of sequentially organic-then-mechanistic management control systems (i.e. 2OM, SOMOM, and ROMOM) appeared to result in better organizational performance, while the frameworks of all organic management control systems (i.e. 2OO, SOOOO, and ROOOO) appeared to result in poor organizational performance. Fast responsiveness of all organic management control systems frameworks may cause extended enterprises to overreact to changes in customer demand and result in excess inventory. However, sequentially organic-then-mechanistic management control systems (i.e. 2OM, SOMOM, and ROMOM) frameworks may prevent the extended enterprise from reacting too fast, because the inefficiency of the mechanistic management control system acts as a dampening mechanism to prevent the extended enterprise from reacting to minor changes in inputs.

The measure of delivery (*OSTDV*) indicates that all mechanistic management control systems frameworks (i.e. 2MM, SMMMM, and RMMMM) are the least effective across all three structures of extended enterprises in dynamic environments (see Table 5.3). Also, with the unpartitionable sequential tasks in stable environments, the management control systems framework with all mechanistic management control systems (i.e. 2MM) is the least effective. No statistical significance was found on the *OSTDV* among different frameworks with the partitionable sequential and reciprocal tasks.

In general, investigating the mean values of the *OSTDV*, the management control systems frameworks with the all organic management control systems (i.e. 2OO, SOOOO, and ROOOO) appeared to result in better organizational performance, while the frameworks of all mechanistic management control systems (i.e. 2MM, SMMMM, and RMMMM) resulted in poor organizational performance. Unlike the financial measure, all organic management control systems frameworks were more effective frameworks since excess inventory identified above allows extended enterprises to deliver products to the customer without time delays due to backlog orders.

The measure of the smoothness of the production flow (*PSTDV*) identifies that the management control systems frameworks of the all mechanistic management control systems (i.e. 2MM, SMMMM, and RMMMM) to be the least effective framework in stable and dynamic environments across all three structures of extended enterprises (see Table 5.3). Furthermore, investigating the mean values of the *PSTDV*, the management control systems frameworks of sequentially organic-then-mechanistic management control systems (i.e. 2OM, SOMOM, and ROMOM) appeared to result in better organizational performance across all three structures of extended enterprises in stable and dynamic environments except with the reciprocal tasks in stable environments. With the reciprocal tasks in stable environments, the all organic management control systems framework (ROOOO) was more effective. The frameworks of all mechanistic management control systems (i.e. 2MM, SMMMM, and RMMMM) result in poor organizational performance.

Additional Scheffé tests were performed to further explore the results of the hypothesis III test. The results of Scheffé tests in Table 5.3 identified effective and ineffective frameworks of management control systems for an extended enterprise operating within a particular combination of environments and types of interactions of management control systems separately in three possible structures of extended enterprises (i.e. unpartitionable sequential, partitionable sequential, and reciprocal structures). Thus, the Table 5.4 reports the results of Scheffé tests which compare the relative effectiveness of three structures of extended enterprises on the organizational performance.

With the financial measure (*FM*), the unpartitionable sequential structure (UNPSEQ) was more effective structure for both stable and dynamic environments. Individual manufacturing units (or supply chains), whether they are managed by the mechanistic or organic management control system, have the same initial inventory level and production capacity. The partitionable sequential (PSEQ) and reciprocal (RECIP) structures with two supply chains initially have more inventory in the systems than the unpartitionable sequential structure (UNPSEQ) with one supply chain, thus the PSEQ and RECIP with two supply chains are more expensive solutions than the UNPSEQ as indicated in Table 5.4 (Note: Even when a sub-experiment was run for 108 weeks, a

Dependent Var.	FM				OSTDV				PSTDV			
Environment	Stable		Dynamic		Stable		Dynamic		Stable		Dynamic	
Structure	Mean	Grp	Mean	Grp	Mean	Grp	Mean	Grp	Mean	Grp	Mean	Grp
	F = 0.0000		***F=0.0002***		***F=0.0001***		***F=0.0000***		***F=0.0000***		***F=0.0000***	
UNPSEQ	894,401	a	2,270,023	a	0.0009	b	0.1563	c	1.21	c	4.72	c
PSEQ	973,262	b	2,352,550	b	0.0000	a	0.0284	a	0.90	a	3.32	a
RECIP	991,966	b	2,404,475	b	0.0009	b	0.0561	b	1.11	b	3.78	b

Note:
- UNPSEQ stands extended enterprises structured to perform for the unpartitionable sequential tasks
- PSEQ stands for extended enterprises structured to perform the partitionable sequential tasks
- RECIP denotes for extended enterprises structured to perform the reciprocal tasks

Table 5.4. Results of the Scheffé tests for structures of extended enterprises: First

similar result was found due to the initial excess inventory of the PSEQ and RECIP). Furthermore, it is reasonable to assume that an extended enterprise with two supply chains would be more expensive to operate than an extended enterprise with only one supply chain since the extended enterprise with two supply chains has to manage extra production capacity and to coordinate activities of two supply chains.

With the measure of delivery (*OSTDV*), again significant differences were found among different structures across stable and dynamic environments. According to Brooks' law (1975), when a group of programmers work on complex reciprocal tasks, "adding (more) manpower to a late software project makes it later" due to the added burden of communication and coordination effort; whereas adding more manpower to partitionable sequential tasks which require little or no communication lead to a stronger coverage of the problem. Analytically, this implies that for extended enterprises structured to perform reciprocal tasks (i.e. RECIP), the involvement of more and more supply chains does not necessarily lead to a stronger coverage of the problem due to the increased coordination costs (or efforts), while it does for extended enterprises structured to perform partitionable sequential tasks (i.e. PSEQ). Thus, the amount of each supply chain's work was decreased by some amount as the number of supply chains increased for extended enterprises performing sequential tasks, and significant differences in measure of delivery between the UNPSEQ (i.e. one supply chain) and PSEQ (i.e. two supply chains) were found as expected. In other words, excess capacity of two supply chains compare to one supply chain help the extended enterprise reduce the number of stockout, thus enable the extended enterprise with two supply chains to deliver the products with less delays. Furthermore, significant differences were found between the PSEQ and RECIP since the RECIP requires added burden of communication and coordination effort comparing to the PSEQ (see Table 5.4).

With the measure of production process (*PSTDV*) which measures the smoothness of the production flow, again the PSEQ was the most effective structure, while the UNPSEQ was the least effective in both stable and dynamic environments (see Table 5.4). The significant differences among structures for the *PSTDV* can be explained with the same arguments made for the *OSTDV*.

The results of main Scheffé tests (see Table 5.3) indicated variations of effective and ineffective management control systems frameworks across the three different measures. Possible explanations for these variations could be that the three performance measures evaluate three different dimensions of organizational performance and individual frameworks of management control systems have different impacts on the three dimensions of organizational performance, and/or there is a model behavior problem that has not been identified. However, with unexpected results of hypotheses II, III, and IV tests for the *FM*, it was determined to pursue the second explanation in the following section.

5.3.3 Discussion

The *FM* directly measures the impact of production and inventory policies, since individual extended enterprises attempt to minimize *Inventory* level while avoiding a backlog of unfilled orders using their production and inventory policies to minimize the costs (*FM*). The results of hypotheses II, III, and IV tests for *FM* imply that different combinations of production and inventory policies may have little statistical impact on the *FM*. Therefore, further investigation of production policies of two basic manufacturing organization models was conducted. However, the inventory policy was not further investigated since two basic models share the same inventory policy (i.e. *Target Inventory (TI)* levels for both models are same for both models).

Recall from the Chapter 4, the following equation represents *Production Rate* (i.e. the production policy):

$$PR = MAX(0, [(SR * dt) + (1/k)*\{[(TI_t - I_t) + OB_t] + (OR - PR) * dt\}])$$

where

PR_t = *Production Rate*
I_t = *Inventory*
TI_t = *Target Inventory*
OB_t = *Order Backlog*
OR = *Order Rate*
SR = *Shipment Rate*
$1/k$ = *reaction rate*
dt = *"delta time" which is the time interval between t-1 and t*

Two basic manufacturing models use this equation to determine their production policies with one exception. The mechanistic management control system determines weekly *Production Rates* based on "after-the-fact summaries of transactions" (Egol *et al.*, 1995) and sends down the decisions to the *Production* function. Thus the new *Production Rate* becomes effective with a time delay as discussed in Section 4.5.1. On the other hand, the organic management control system calculates weekly *Production Rate* based on current transactions and executes the decision without a time delay as discussed in Section 4.5.2. Therefore, the organic management control system inherently reacts faster to any changes in inputs.

Reaction rate (*1/k*) in the equation (R.1) is a time constant representing the rate at which management on average, reacts to make a necessary adjustment on inventory- and pipeline-deficit situations. With this experiment setting, the *reaction rates* for the mechanistic management control system and the organic management control system were set with a same value 1/1.5. This rate resulted in optimal performance of the single manufacturing unit with the mechanistic management control system when we tested the model with the Beer Distribution Game.

With this *reaction rate*, which is finely tuned for optimal performances of a manufacturing unit with the mechanistic management control system, a manufacturing unit with the organic management control system always produces too much, too fast. As a result, the manufacturing unit with the organic management control system produces excess *Inventory* and this excess effectively helps the manufacturing unit avoiding a backlog of unfilled orders. Therefore, the measure of costs (*FM*) identified management control systems frameworks with all organic nodes (i.e. 2OO, SOOOO, and ROOOO) as the least effective framework. Whereas, the measure of delivery (*OSTDV*) identified this same management control systems framework as the most effective one for extended enterprises since the excess *Inventory* level prevented such extended enterprises from having backlog orders.

Theoretically, the fact that the organic management control system can react faster than the mechanistic one was identified before the experiment; however we failed to implement an adjustment of the reaction rate of the organic management control system appropriately.

Therefore, in order to prevent this biased model behavior, the following changes in the models and experiment setting were implemented for the subsequent experiment.

Reaction Rate for the Organic Management Control System

We have identified that the reaction rate, 1/1.5 was too responsive for the organic management control systems. Thus, dynamically changing and less responsive reaction rates for the organic management control systems were implemented, while the reaction rate of 1/1.5 continued to be used with the mechanistic management control system.

The following equation represents the *Reaction Rate* for the organic management control system:

$$1/k = \begin{cases} 1/8 & if\,(TI_t - I_t > OR/3) \\ 1/1.5 & if\,(0 < TI_t - I_t \leq OR/3) \\ 1/5 & if\,(TI_t - I_t \leq 0) \end{cases}$$

Larger $1/k$ values emphasize recent changes in customer demands and result in production decisions more responsive to changes in the underlying average, while smaller $1/k$ values treat past demands more uniformly and result in more stable production decisions. The management cycle time of the manufacturing unit with the organic management control system is three times faster than the one with the mechanistic management control system (i.e. 0.25 weeks vs. 0.75 weeks). Thus, when the inventory-deficit situation (i.e. $TI_t - I_t$) is less than or equal to one third of the Customer Order (i.e. *OR/3*), but larger than zero, the organic management control system uses the same reaction rate (i.e. 1/1.5) as the mechanistic one. However, when $TI_t - I_t$ becomes larger than *OR/3*, or smaller than or equal to zero, less responsive reaction rates, 1/8 and 1/5 respectively, are employed to make production decisions.

When a manufacturing unit receives an irregularly large order in one period, it usually results in $TI_t - I_t > OR/3$ since *TI* is a multiple of an *Customer Order* (*OR*), thus in order to treat past demands more uniformly as well as in anticipation of getting more typical (i.e. smaller) order size, less reactive rate 1/8 is used. However, when a manufacturing unit gets a smaller than typical order size, it usually results in $TI_t - I_t \leq 0$ (i.e. the actual *Inventory* level is larger than *Target Inventory* level), thus in order to treat past demands more uniformly, but in anticipation of getting larger order, a more reactive rate 1/5 is used. This rate is more responsive than 1/8, but still less reactive than 1/1.5. The reaction rate is identified as "one of the more critical parameters in determining the system's dynamic performance" (Forrester, 1961), the future replications of this study should investigate the relationship between the reaction rate and the behavior of the system more extensively.

Power of the Test and Sample Size

With this first experiment, a sample size of 100 was used. However with the results of this experiment, power analysis was used to determine a number of data sets of each factor setting required to produce the probability that a statistical test would result in statistical significance (i.e. statistical power). Power analysis was performed using Power Analysis and Sample Size (PASS), version 6.0 for Microsoft Windows to calculate statistical power and determine sample size (i.e. a number of experiments).

The result of power analysis with $\alpha = 0.05$ and $\beta = 0.01$ indicated that a sample size as small as 12 would produce a statistically powerful result. However, in order to assure strong power on statistical analysis of the experiments, it was determined to use a sample size of 50 in the subsequent experiments. Marginal costs of performing 50 simulation runs, in terms of time, compared to 12 were not significant; however collecting 100 were. Therefore, we used a sample size of 50.

Environments

Although the results of the first experiment did not seem to show any problem with the fluctuation ranges for two external environments, we determined to use a range which results in less fluctuating customer demands for stable environments. With the first experiment, -100% to +210% fluctuation of customer demand base level (*CBL:* 4,000 units/week) was assumed to simulate stable environments; however in the subsequent experiment, ± 50% fluctuation of *CBL* was assumed to simulate stable environments, while - 100% to + 600% of *CBL* was again assumed to simulate dynamic environments.

5.4 Second Experiment

With the changes made in the models and experiment settings, the second set of experiments was performed. For each experimental factor setting, 50 cases of experiment results were collected for a total of 2,400 cases. Furthermore, each set of 2,400 experiments was replicated with three different time delay parameters in order to examine the effect of varying management cycle time (time from order receipt to production order) of the management function, while fixing manufacturing cycle time (time from material receipt to product shipment) of the production function.

According to Hill (1994), it is often manufacturing infrastructure --also termed as the nonprocess aspects of manufacturing and software-- that varies tremendously between companies and determines the success or failure of a manufacturing organization, rather than the choice of manufacturing processes and technologies, also termed as hardware. Hill (1994) argues that the manufacturing organizations in similar industries and market have access to the similar manufacturing processes and technologies. Therefore, the effect of varying management cycle time of the management function (which represents "software"), while fixing manufacturing cycle time of the production function (which represents "hardware") is examined. Hereafter these three sets of 2,400 experiments are referred to as the Optimistic, Basic, and Pessimistic models.

The delay parameter (*dp*) was set to be 0.0275, 0.25, and 0.294 weeks for the Optimistic, Basic, and Pessimistic models respectively. According to Bookbinder and Dilts (1989), a survey by La Londe and Zinszer (1976) indicated that the average total order cycle time, the time between the order placement to order receipt to be 10.3 days. But more recent literature revealed that the leaders in many industries have been trying to push the order cycle time down to under 24 hours (FourGen Software 1996; Silver Brook System 1996). Therefore, the order cycle of the manufacturing entity with the mechanistic management control system in the Pessimistic model was set to be 10.3 days according to the survey by La Londe and Zinszer (1976), while the one in the Optimistic model was set to be under 24 hours. The order cycle of the manufacturing entity with the mechanistic management control system in the Basic model was set with the initial delay parameter (*dp*) value of 0.25 weeks, and thus resulted in 8.75 days of the order cycle in the second experiment.

However, the original *DT* (Delta Time) setting employed to develop the basic single manufacturing organization models was set to be 0.25 week[1], and *DT* of 0.25 week prevented manufacturing cycle time from modification unless a unit of 0.25 increment or decrement in the artificial delay parameter (*dp*) was made. *DT* is the interval of time between calculations and the model re-calculates its numerical values once every 1/4 of a week. This resulted in the manufacturing cycle time of the three models to be constant, while the management cycle time of the management function to be varied in proportion to the artificial delay parameter (i.e. *dp*). Therefore, these three settings allow us to examine the effect of varying management cycle time of the management function, while fixing manufacturing cycle time. The Optimistic, Basic, and Pessimistic models of the manufacturing unit with the organic management control system were arranged using the same delay parameter (*dp*) variables used in each respective case of the mechanistic ones. Table 5.5 summarizes three (revised) order cycles.

Each experiment was again performed over a period of 54 simulated weeks. The input variable of each simulation run --customer order in each week-- was randomly generated. Table 5.6 summarizes the second experiment settings.

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[1] . DT of 0.25 week was recommended in ithink® Technical Documentation (High Performance Systems, Inc. 1996).

		Optimistic Model delay parameter(dp): 0.0275 weeks	Basic Model delay parameter(dp): 0.25 weeks	Pessimistic Model delay parameter(dp): 0.294 weeks
Mechanistic	MgmtCT	0.5775 day (0.0825 weeks)	5.25 days (0.75 weeks)	6.174 days (0.8820 weeks)
	MfgCT	3.5 days (0.5 weeks)	3.5 days (0.5 weeks)	3.5 days (0.5 weeks)
	Total OCT	**4.078 days (0.5825 weeks)**	**8.75 days (1.25 weeks)**	**9.674 days (1.382 weeks)**
Organic	MgmtCT	0.1925 day (0.0275 weeks)	1.75 day (0.25 weeks)	2.05 days (0.294 weeks)
	MfgCT	3.5 days (0.5 weeks)	3.5 days (0.5 weeks)	3.5 days (0.5 weeks)
	Total OCT	**3.693 days (0.5275 weeks)**	**5.25 days (0.75 weeks)**	**5.558 days (0.794 weeks)**

Note: •MgmtCT stands for management cycle time
•MfgCT stands for manufacturing cycle time.
•OCT stands for order cycle time.
•7 working days a week.
•Delay parameter manipulates the order cycle of individual manufacturing unit.

Table 5.5 Three sets of order cycle time for the second experiment

	Optimistic	Basic	Pessimistic
Number of factor settings	48	48	48
Number of replications per factor setting	50	50	50
Total number of cases	2,400	2,400	2,400
Total number of periods (T)	54 weeks	54 weeks	54 weeks
Total number of individual manufacturing units (N)	2 or 4	2 or 4	2 or 4
Customer Demand			
Base Level (CBL)	4,000 units/week	4,000 units/week	4,000 units/week
Environments (*2 levels*)			
Stable	-50% to +50% of base	-50% to +50% of base	-50% to +50% of base
Dynamic	-100% to +600% of base	-100% to +600% of base	-100% to +600% of base
Delay Parameter (dp)	0.0275 weeks	0.25 weeks	0.294 weeks
Management Cycle Time			
Mechanistic	0.0825 weeks	0.75 weeks	0.882 weeks
Organic	0.0275 weeks	0.25 weeks	0.294 weeks
Manufacturing Cycle Time			
Mechanistic	0.50 weeks	0.50 weeks	0.50 weeks
Organic	0.50 weeks	0.50 weeks	0.50 weeks
Reaction Rate ($1/k$)			
Mechanistic	1/1.5	1/1.5	1/1.5
Organic	1/8, if $TI_t - I_t > OR/3$ 1/1.5, if $0 < TI_t - I_t \leq OR/3$ 1/5, if $TI_t - I_t \leq 0$	1/8, if $TI_t - I_t > OR/3$ 1/1.5, if $0 < TI_t - I_t \leq OR/3$ 1/5, if $TI_t - I_t \leq 0$	1/8, if $TI_t - I_t > OR/3$ 1/1.5, if $0 < TI_t - I_t \leq OR/3$ 1/5, if $TI_t - I_t \leq 0$
Cost of Inventory/week (C_I)	$0.50/week	$0.50/week	$0.50/week
Cost of Backlog/week (C_B)	$1.00/week	$1.00/week	$1.00/week

Table 5.6. Summary of the second experiment settings

5.4.1 Hypotheses Testing

Four hypotheses presented in Chapter Three were tested in this section with the three sets of 2,400 experiment results and the dependent variables described in Section 5.2. Table 5.7 summarizes the results of hypotheses tests.

Models	*Dependent Variables*	*Independent Variables*			
		ENV H_1 *p-value*	INTER H_2 *p-value*	STRUCT H_3 *p-value*	ENV x INTER H_4 *p-value*
Optimistic Model	*FM*	0.000	**0.002**	0.000	0.000
	OSTDV	0.000	0.000	0.000	0.000
	PSTDV	0.000	0.000	0.000	0.000
Basic Model	*FM*	0.000	0.000	**0.018**	0.000
	OSTDV	0.000	0.000	0.000	0.000
	PSTDV	0.000	0.000	0.000	0.000
Pessimistic Model	*FM*	0.000	0.000	**0.019**	0.000
	OSTDV	0.000	0.000	0.000	0.000
	PSTDV	0.000	0.000	0.000	0.000

Note:
- *FM* stands for financial measure.
- *OSTDV* represents deviation of order delivery time.
- *PSTDV* represents standard deviation of manufacturing cycle time.
- ENV stands for environments.
- INTER represents interactions of management control systems.
- STRUCT stands for structure.
- ENV x INTER denotes interactions between ENV and INTER.

Table 5.7 Summary results of ANOVA tests of the second experiment

Hypothesis IV which investigates the effect of interactions of the three contingent factors on organizational performance resulted in the expected findings that particular combinations of the three factors have significantly different impacts on organizational performance for all three dimensions of performance across all three models.

Hypothesis I which examines the effect of different types of environments on organizational performance was rejected for all three dimensions of performance across three models as the results of ANOVAs presented in Table 5.7. In other words, the results of experiments suggest that changes in environmental conditions have statistically significant effects on organizational performance of an extended enterprise. However further investigating the effect of each contingent factor on organizational performance using hypotheses II and III tests resulted in conflicting outcomes depending on the model and the performance measure used.

As the results presented in Table 5.7 indicate, hypothesis II was not rejected for the financial measure (*FM*) with the Optimistic model contrary to the prediction, whereas it was rejected with the measures of delivery (*OSTDV*) and production flow (*PSTDV*). However with the Basic and Pessimistic models, the hypothesis II was rejected for all three performance measures.

Hypothesis III which examines the effect of different structures of extended enterprises on organizational performance was rejected for all three dimensions of performance measure with the Optimistic model. However, it was not rejected for the financial measure (*FM*) with the Basic and Pessimistic models, but rejected for the measures of delivery (*OSTDV*) and production flow (*PSTDV*).

The results of the four hypotheses tests partially support our fundamental premises of this research that not only each contingent factor, but also the interaction among all three contingent factors has effect on organizational performance of an extended enterprise depending on the performance measure used. Therefore, further investigation of the interaction of these three contingent factors across the three models was pursued in the following section.

5.4.2 *Post Hoc* Analyses

One-way analysis of variance (ANOVA) with *post hoc* Scheffé multiple comparison tests was employed to identify effective or ineffective frameworks of management control systems for an extended enterprise operating within a particular combination of the contingent factors across the three models. Each model will be tested individually and the results of the Scheffé tests for the Optimistic model is discussed first.

5.4.2.1 Optimistic Model

The Optimistic model is described as a manufacturing organization where the management cycle time is significantly faster than the manufacturing cycle time. For manufacturing units with the mechanistic management control system, the management cycle time is 0.0825 weeks and the manufacturing cycle time is 0.50 weeks. On the other hand, for manufacturing units with the organic management control system, the management cycle time is 0.0275 weeks and the manufacturing cycle time is 0.50 weeks. Table 5.8 summarizes the results of the Scheffé tests of the Optimistic model.

As presented in Table 5.8, the financial measure (*FM*) indicates that the all mechanistic management control systems framework (i.e. 2MM) to be the least effective framework with extended enterprises structured to perform the unpartitionable sequential tasks in both stable and dynamic environments. While there are no statistical differences among the other frameworks (i.e. 2OO, 2OM, and 2MO), the all organic management control systems framework (i.e. 2OO) appear to result in better organizational performance. Interestingly, while the ANOVA test exhibits significant differences at α = 0.0001 among different management control systems frameworks with the partitionable sequential tasks in stable environments for the *FM*, the Scheffé tests indicate that all pairs of means are not significantly different from each others at α = 0.05. Whereas, with extended enterprises structured to perform the partitionable sequential tasks in dynamic environments, no statistical significance is found for the *FM* among different frameworks of management control systems. Furthermore, with extended enterprises structured to perform the reciprocal tasks, the management control systems framework of all mechanistic management control systems (i.e. RMMMM) is the least effective framework across stable and dynamic environments.

Overall, investigating the mean values of the *FM*, the management control systems frameworks of all mechanistic management control systems frameworks (i.e. 2MM, SMMMM, and RMMMM) appear to result in poor organizational performance. While 2OO, SOOOM, and ROOOO in stable environments and 2OO, SOOOM, and ROMOM are more effective frameworks. Although there

Second Experiment: Optimistic Model												
Dependent Var.	FM				OSTDV				PSTDV			
Environment	Stable		Dynamic		Stable		Dynamic		Stable		Dynamic	
	Mean	Grp	Mean	Grp	Mean	Grp	Mean	Grp	Mean	Grp	Mean	Grp
Unpartitionable sequential tasks	*F = 0.0000*		*F=0.0003*		-		*F=0.2650*		*F=0.0000*		*F=0.0000*	
2MM	*698,620*	*b*	*1,985,599*	*b*	.0000	n/a	.1572	n/a	*.4474*	*b*	4.358	*c*
2MO	661,936	a	1,665,931	a	.0000		**.1356**		.3144	a	3.470	b
2OM	664,505	a	1,550,366	a	.0000		*.1696*		.3110	a	**2.813**	**a**
2OO	**648,397**	**a**	**1,498,787**	**a**	.0000		.1562		**.2714**	**a**	2.935	a
Partitionable sequential tasks	*F=0.0000*		*F=0. 0053*		-		*F=0.9116*		*F=0.0000*		*F=0.0000*	
SMMMM	751,171	a	1,977,509	n/a	.0000	n/a	*.0120*	n/a	**.4270**	**a**	*2.859*	*c*
SMMMO	747,905	a	1,850,105		.0000		.0078		.5630	a	2.576	b
SMMOM	741,301	a	1,842,544		.0000		.0118		.4340	a	2.444	a
SMMOO	740,186	a	1,825,456		.0000		.0080		.6674	b	2.459	a
SMOMO	*751,410*	*a*	1,811,608		.0000		**.0036**		.6926	b	2.285	a
SMOOM	742,765	a	1,786,318		.0000		.0058		.5716	a	2.162	a
SOMOM	729,983	a	1,699,924		.0000		.0082		.4476	a	2.024	a
SOOMO	747,472	a	1,796,959		.0000		.0038		.7946	c	2.266	a
SOOOM	**728,424**	**a**	1,699,599		.0000		.0060		.6768	b	2.022	a
SOOOO	731,687	a	1,737,767		.0000		.0040		*.8992*	d	**2.019**	**a**
Reciprocal tasks	*F=0.0000*		*F=0.0000*		-		*F=0.1752*		*F=0.0000*		*F=0.0000*	
RMMMM	*782,842*	*d*	*2,166,934*	*b*	.0000	n/a	*.0326*	n/a	.5798	a	*3.344*	*d*
RMMMO	769,749	c	2,028.932	a	.0000		.0146		.6034	a	2.863	c
RMMOM	756,394	b	1,954,994	a	.0000		.0312		.5064	a	2.693	b
RMMOO	753,804	a	1,966,174	a	.0000		.0250		.6868	c	2.731	b
RMOMO	756,657	b	1,890,930	a	.0000		**.0000**		.6272	b	2.381	a
RMOOM	743,301	a	1,816,992	a	.0000		.0146		.5294	a	2.212	a
ROMOM	729,946	a	**1,743,055**	**a**	.0000		.0294		**.4330**	**a**	**2.043**	**a**
ROOMO	744,757	a	1,846,554	a	.0000		.0162		.7158	d	2.366	a
ROOOM	727,355	a	1,754,234	a	.0000		.0236		.6124	b	2.081	a
ROOOO	**724,765**	**a**	1,765,413	a	.0000		.0174		*.7926*	*e*	2.121	a

Table 5.8. Results of the Scheffé tests for the Optimistic Model: Second Experiment

are some variations, management control systems frameworks with organic management control systems organized near the customer perform better with the modified reaction rates (*1/k*) for the organic management control systems. Unlike the results of the first experiment, the modified reaction rates of the organic management control systems prevent the extended enterprise from producing products too much, too fast.

The measure of delivery (*OSTDV*) does not show significant differences among different frameworks of management control systems with all three structures of extended enterprises in both stable and dynamic environments. In fact, in stable environments, the results indicates that all frameworks of management control systems can help an extended enterprise satisfy customer order without having any backlog orders. While the differences among the *OSTDVs* in dynamic environments are small, no statistical difference is found.

On the other hand, the measure of production process or the smoothness of the production flow (*PSTDV*) identifies that the management control systems framework of all mechanistic management control systems to be the least effective in stable and dynamic environments with the unpartitionable sequential tasks (see Table 5.8). Interestingly, with partitionable sequential tasks in stable environments, the all mechanistic management control systems framework (i.e. SMMMM) is the most effective, while the all organic management control systems framework (i.e. SOOOO) is the least effective.

Investigating the *FM*, *OSTDV*, and *PSTDV* of both SMMMM and SOOOO in stable environments revealed that higher variability of SOOOO in production process helped the extended enterprise to keep its inventory level lower than the SMMMM, thus resulted in better *FM* for SOOOO. Since both frameworks did not have backlog orders (i.e. *OSTDV* of both frameworks were zero) in stable environments, the *FMs* directly measured the inventory levels of extended enterprises. Therefore, the framework with more responsive organic management control systems (i.e. SOOOO) varied production flows as the customer order demands (i.e. *OR*) changed even in small amounts, while the framework with less responsive mechanistic management control systems (i.e. SMMMM) kept its production flow relatively smooth and constant regardless of small changes in customer demands, thus resulted in excess inventory levels. However as environments become dynamic, the more responsive SOOOO helps extended enterprises to keep its production flow relatively smoother than the less responsive and slower SMMMM.

Furthermore, comparing the *PSTDVs* of 2MM, 2OO, SMMMM, and SOOOO in stable environments identified that a supply chain with all mechanistic management control systems can keep production flow smoother than the ones with all organic management control systems only when the fluctuation coming from the customer is very small (in other words, when the external environments are very stable). Individual supply chains in extended enterprises structured to perform partitionable sequential tasks (PSEQ) inherently face less fluctuating external environments than a single supply chain in extended enterprises structured to perform unpartitionable sequential tasks (UNPSEQ) under an identical situation. For example, if the customer demand suddenly leaps to 8,000 from 4,000 units, one supply chain in UNPSEQ has to manage the entire 4,000 increase in demand, however two supply chains in PSEQ manage 2,000 increase in demand individually thus each supply chain confronts a smaller fluctuation. Therefore, although the 2MM appears to be less effective than the 2OO for the *PSTDV* in stable environments, the SMMMM appears to be a more effective framework than the SOOOO in stable environments. However as the environments become dynamic, all organic management control systems frameworks (i.e. 2OO, SOOOO, ROOOO) appear to be more effective.

This finding is also supported by the results of *PSTDV* in the first experiment. Recall that -100% to +210% fluctuation of customer demand base level (*CBL:* 4,000 units/week) was used to simulate stable environments in the first experiment, whereas -50% to +50% fluctuation of customer demand base level was used to simulate stable environments in this experiment. Therefore, less stable environments of the first experiment resulted in the SOOOO to be more effective framework than the SMMMM for the *PSTDV* even in stable environments with the first experiment.

Similarly, with extended enterprises structured to perform the reciprocal tasks, all organic management control systems framework (i.e. ROOOO) was the least effective management control systems framework for the *PSTDV* in stable environments, while all mechanistic management control systems framework (i.e. RMMMM) was the least effective one in dynamic environments.

5.4.2.2 Basic Model

The manufacturing and management cycle times of the Basic model are set with the initial *dp* value of 0.25. For manufacturing units with the mechanistic management control system, the management cycle time is 0.75 weeks and the manufacturing cycle time is 0.50 weeks. On the other hand, for manufacturing units with the organic management control system, the management cycle time is 0.25 weeks and the manufacturing cycle time is 0.50 weeks. Table 5.9 summarizes the results of the Scheffé tests for the Basic model.

The financial measure indicates that all mechanistic management control systems frameworks (i.e. 2MM, SMMMM, and RMMMM) to be the least effective frameworks across all three structures of extended enterprises in both stable and dynamic environments (see Table 5.9). *FM* also identifies groups of management control systems frameworks to be statistically effective frameworks across all three structures of extended enterprises in stable and dynamic environments; although the difference is not statistically significant, all organic management control systems frameworks (i.e. 2OO, SOOOO, and ROOOO) appeared to be more effective within each structure of extended enterprises in stable environments, whereas, 2OO, SOMOM and ROOOO are appeared to be more effective in dynamic environments.

The measure of delivery (*OSTDV*) again does not show any significant differences among different frameworks of management control systems with all three structures of extended enterprises in both stable and dynamic environments.

Second Experiment: Basic Model												
Dependent Var.	FM				OSTDV				PSTDV			
Environment	Stable		Dynamic		Stable		Dynamic		Stable		Dynamic	
	Mean	Grp	Mean	Grp	Mean	Grp	Mean	Grp	Mean	Grp	Mean	Grp
Unpartitionable sequential tasks	***F = 0.0000***		***F = 0.0000***		·		***F=0.6342***		***F=0.0000***		***F=0.0000***	
2MM	*768,231*	*c*	*2,307,052*	*b*	.0000	n/a	.1794	n/a	*.9268*	*c*	*5.546*	*c*
2MO	679,240	b	1,783,765	a	.0000		.1652		.4426	b	3.779	b
2OM	665,582	a	1,606,054	a	.0000		.1770		.4138	a	**2.879**	**a**
2OO	**638,466**	**a**	**1,560,417**	**a**	.0000		.1618		**.2776**	**a**	2.890	a
Partitionable sequential tasks	***F = 0.0000***		***F = 0.0000***		·		***F=0.0059***		***F=0.0000***		***F=0.0000***	
SMMMM	*813.383*	*d*	*2,267,349*	*b*	.0000	n/a	*.0496*	n/a	.7294	b	*3.792*	*d*
SMMMO	791.850	c	2,095,766	a	.0000		.0280		.6846	b	3.111	c
SMMOM	773.264	b	2,012,343	a	.0000		.0340		.5898	a	2.921	b
SMMOO	771.508	b	2,037,356	a	.0000		.0294		.7902	d	2.899	b
SMOMO	770.318	b	1,924,182	a	.0000		**.0060**		.6406	a	2.430	a
SMOOM	751.731	a	1,840,760	a	.0000		.0122		.5458	a	2.240	a
SOMOM	733.144	a	**1,757,338**	**a**	.0000		.0180		**.4510**	**a**	2.051	a
SOOMO	751.421	a	1,885,181	a	.0000		.0222		.7616	c	2.305	a
SOOOM	731.389	a	1,782,350	a	.0000		.0136		.6512	b	2.027	a
SOOOO	**729.633**	**a**	1,807,362	a	.0000		.0090		*.8518*	*e*	**2.004**	**a**
Reciprocal tasks	***F = 0.0000***		***F = 0.0000***		·		***F=0.0751***		***F=0.0000***		***F=0.0000***	
RMMMM	*830,962*	*e*	*2,373,767*	*c*	.0000	n/a	*.0810*	n/a	*1.019*	*e*	*4.346*	*d*
RMMMO	801,538	d	2,150,862	b	.0000		.0706		.8272	c	3.580	c
RMMOM	781,390	c	2,078,320	a	.0000		.0570		.7676	b	3.330	b
RMMOO	775,738	c	2,058,596	a	.0000		.0570		.8638	d	3.237	b
RMOMO	772,114	b	1,927,957	a	.0000		.0608		.6362	a	2.814	a
RMOOM	751,966	a	1,855,415	a	.0000		.0468		.5760	a	2.564	a
ROMOM	731,817	a	1,782,873	a	.0000		**.0334**		**.5166**	**a**	2.313	a
ROOMO	745,613	a	1,836,455	a	.0000		.0544.		.6768	a	2.500	a
ROOOM	726,165	a	1,763,149	a	.0000		**.0334**		.6128	a	2.222	a
ROOOO	**720,514**	**a**	**1,743,426**	**a**	.0000		**.0334**		.7088	a	**2.130**	**a**

Table 5.9. Results of the Scheffé tests for the Basic Model: Second Experiment

The measure of smoothness of production flow (*PSTDV*) indicates that all mechanistic management control systems frameworks (i.e. 2MM) to be the least effective with the unpartitionable sequential tasks in stable and dynamic environments (see Table 5.9). 2OO and 2OM are effective management control systems frameworks to keep production flow smooth in both stable and dynamic environments. The difference is not statistically significant between 2OO and 2OM, but the 2OO results in lower variability in production flow in stable environments, while 2OM keeps its production flow the smoothest in dynamic environments.

The *PSTDV* identifies all organic management control systems framework (i.e. SOOOO) to be less effective to keep production flow smooth in stable environments, while all mechanistic management control systems (i.e. SMMMM) to be less effective framework in dynamic environments. As discussed with the Optimistic model in Section 5.4.2.1, the frameworks with all mechanistic management control systems help an extended enterprise keep its production flow smoother than the frameworks with all organic management control systems when customer order fluctuation is very small. However, with the reciprocal tasks, all mechanistic management control systems framework (i.e. RMMMM) is less effective for the *PSTDV* even in stable environments (as well as in dynamic environments). Unlike the result of the Optimistic model (i.e. RMMMM is still identified as more effective than the ROOOO for the *PSTDV*), slower management cycle times of the Basic model than the ones in the Optimistic model plus extra coordination costs in terms of time narrowed the range where the RMMMM to effectively control the production flow smoother than the ROOOO.

5.4.2.3 Pessimistic Model

For manufacturing units in the Pessimistic model with the mechanistic management control system, the management cycle time is 0.882 weeks and the manufacturing cycle time is 0.50 weeks. On the other hand, for manufacturing units with the organic management control system, the management cycle time is 0.294 weeks and the manufacturing cycle time is 0.50 weeks. Table 5.10 summarizes the results of the Scheffé tests for the Pessimistic model.

Second Experiment: Pessimistic Model												
Dependent Var.	FM				OSTDV				PSTDV			
Environment	Stable		Dynamic		Stable		Dynamic		Stable		Dynamic	
	Mean	Grp	Mean	Grp	Mean	Grp	Mean	Grp	Mean	Grp	Mean	Grp
Unpartitionable sequential tasks	*F = 0.0000*		*F = 0.0000*		.		*F=0.2217*		*F=0.0000*		*F=0.0000*	
2MM	*743,246*	*b*	*2,260,366*	*b*	.0000	n/a	*.1752*	n/a	*.8114*	*b*	*5.294*	*c*
2MO	674,046	a	1,753,488	a	.0000		.1552		.4134	a	3.618	b
2OM	665,844	a	1,580,633	a	.0000		.1566		.3878	a	2.801	a
2OO	**645,653**	**a**	**1,528,065**	**a**	.0000		**.1452**		**.2682**	**a**	**2.789**	**a**
Partitionable sequential tasks	*F = 0.0000*		*F = 0.0000*		.		*F=0.1209*		*F=0.0000*		*F=0.0000*	
SMMMM	*786,490*	*c*	*2,227,150*	*b*	.0000	n/a	*.0464*	n/a	.6130	b	*3.502*	*e*
SMMMO	771,936	b	2,063,609	a	.0000		.0366		.6228	b	2.919	d
SMMOM	756,608	a	1,986,525	a	.0000		.0360		.5040	a	2.788	c
SMMOO	758,138	a	1,997,249	a	.0000		.0292		.7258	c	2.734	b
SMOMO	757,381	a	1,900,069	a	.0000		.0276		.6338	b	2.336	a
SMOOM	742,053	a	1,822,984	a	.0000		.0214		.5152	a	2.205	a
SOMOM	**726,725**	**a**	**1,745,900**	**a**	.0000		.0148		**.3962**	**a**	2.074	a
SOOMO	746,162	a	1,852,741	a	.0000		.0226		.7386	c	2.232	a
SOOOM	728,255	a	1,756,624	a	.0000		.0136		.6166	b	2.021	a
SOOOO	729,785	a	1,767,347	a	.0000		**.0122**		*.8392*	*d*	**1.967**	**a**
Reciprocal tasks	*F = 0.0000*		*F = 0.0000*		.		*F=0.9951*		*F=0.0000*		*F=0.0000*	
RMMMM	*804,208*	*e*	*2,306,716*	*c*	.0000	n/a	.0478	n/a	*.9102*	*d*	*4.026*	*d*
RMMMO	782,709	d	2,103,136	b	.0000		.0492		.7734	b	3.343	c
RMMOM	765,586	c	2,032,503	a	.0000		.0426		.6892	a	3.152	b
RMMOO	762,546	b	2,008,986	a	.0000		.0426		.8070	c	3.086	b
RMOMO	761,209	a	1,899,555	a	.0000		*.0506*		.6378	a	2.658	a
RMOOM	744,087	a	1,828,922	a	.0000		.0440		.5530	a	2.468	a
ROMOM	726,964	a	1,758,289	a	.0000		**.0374**		**.4688**	**a**	2.278	a
ROOMO	740,815	a	1,805,761	a	.0000		.0426		.6764	a	2.419	a
ROOOM	723,924	a	1,734,772	a	.0000		.0376		.5856	a	2.215	a
ROOOO	**720,885**	**a**	**1,711,255**	**a**	.0000		.0378		.7046	a	**2.151**	**a**

Table 5.10. Results of the Scheffé tests for the Pessimistic Model: Second Experiment

The financial measure indicates that all mechanistic management control systems frameworks to be the least effective frameworks with all three structures of extended enterprises in both stable and dynamic environments (see Table 5.10). *FM* also identifies a group of management control systems frameworks to be statistically effective frameworks within each of three structures of extended enterprises in stable and dynamic environments.

The measure of delivery (*OSTDV*) does not show any significant differences among different frameworks of management control systems across all three structures of extended enterprises in both stable and dynamic environments.

PSTDV indicates that all mechanistic management control systems frameworks (i.e. 2MM) to be the least effective framework with extended enterprises structured to perform the unpartitionable sequential tasks in stable and dynamic environments. While 2OO and 2OM are effective management control systems frameworks to keep production flow smooth in both stable and dynamic environments. Furthermore, *PSTDV* identifies all organic management control systems framework (i.e. SOOOO) to be a less effective framework to keep production flow smooth in stable environments, while the framework with all mechanistic management control systems (i.e. SMMMM) is less effective framework in dynamic environments. In fact, in dynamic environments, as long as there is no one supply chain structured with all mechanistic management control systems, management control systems frameworks such as SOOOO, SOOOM, SOOMO, SMOOM, and SMOMO are effective frameworks. This pattern is also found with extended enterprises structured to perform the reciprocal tasks in both stable and dynamic environments.

Additional Scheffé tests were completed to further explore the results of the hypothesis III test. The results of main Scheffé tests in Tables 5.8, 5.9, and 5.10 identified effective and ineffective frameworks of management control systems for an extended enterprise operating within a particular combination of environments and types of interactions of management control systems separately in three possible structures of extended enterprises (i.e. unpartitionable sequential, partitionable

Additional Scheffé tests for the Second Experiment												
Dependent Var.	FM				OSTDV				PSTDV			
Environment	Stable		Dynamic		Stable		Dynamic		Stable		Dynamic	
Structure	Mean	Grp	Mean	Grp	Mean	Grp	Mean	Grp	Mean	Grp	Mean	Grp
Optimistic Model	*F=0.0000*		*F=0.0000*		-		*F=0.0000*		*F=0.0000*		*F=0.0000*	
UNPSEQ	668,364	a	1,675,171	a	0.0000	n/a	.1547	c	.3360	a	3.3939	c
PSEQ	741,230	b	1,802,779	b	0.0000		.0071	a	.6174	b	2.3121	a
RECIP	748,957	c	1,893,421	c	0.0000		.0206	b	.6087	b	2.4837	b
Basic Model	*F=0.0000*		*F=0.0011*		-		*F=0.0000*		*F=0.0000*		*F=0.0000*	
UNPSEQ	687,880	a	1,814,322	a	0.0000	n/a	.1709	c	.5152	a	3.7737	c
PSEQ	761,764	b	1,940,999	b	0.0000		.0222	a	.6696	b	2.5780	a
RECIP	763,782	b	1,957,082	b	0.0000		.0528	b	.7205	c	2.9037	b
Pessimistic Model	*F=0.0000*		*F=0.0007*		-		*F=0.0000*		*F=0.0000*		*F=0.0000*	
UNPSEQ	682,197	a	1,780,638	a	0.0000	n/a	.1581	c	.4702	a	3.6255	c
PSEQ	750,353	b	1,912,020	b	0.0000		.0255	a	.6205	b	2.4780	a
RECIP	753,293	b	1,918,990	b	0.0000		.0432	b	.6806	c	2.7798	b

Note:
- UNPSEQ stands extended enterprises structured to perform for the unpartitionable sequential tasks
- PSEQ stands for extended enterprises structured to perform the partitionable sequential tasks
- RECIP denotes for extended enterprises structured to perform the reciprocal tasks

Table 5.11. Results of the additional Scheffé tests for the Second Experiment

sequential, and reciprocal structures) in each model. Thus, the Table 5.11 reports the results of Scheffé tests which compare the relative effectiveness of three structures of extended enterprises on the organizational performance in each model.

With the financial measure, the structure of extended enterprises was identified to have impact on the organizational performance and the unpartitionable sequential structure (UNPSEQ) is a more effective structure for both stable and dynamic environments across all three models as discussed in Section 5.3.2.

OSTDV did not show significant differences among different frameworks across all three structures in stable environments. In fact, in stable environments, the results indicate that all three extended enterprise structures can help an extended enterprise satisfy customer order without having backlog orders. However with all three models in dynamic environments, significant differences were found among different structures and the PSEQ was identified as the most effective structure, while the UNPSEQ was identified as the least effective as discussed in Section 5.3.2.

With the measure of production process (*PSTDV*), the partitionable sequential structure (PSEQ) is the most effective structure, while the least effective one is the unpartitionable sequential structure (UNPSEQ) in the dynamic environment. However in the stable environment, the UNPSEQ is the most effective structure, contrary to the prediction. In fact, we failed to find a logical explanation for this result for the *PSTDV*. However comparing the results of the additional Scheffé tests for the *PSTDV* of the first experiment with this result revealed that the UNPSEQ appears to result in better organizational performance for both *FM* and *PSTDV* when external environment is very stable. The less stable environment of the first experiment resulted in the UNPSEQ to be less effective structure than the other structures for the *PSTDV* even in the stable environment with the first experiment. In fact, this result suggests that when the external environment is very stable, there is no competitive advantage to have involved more supply chains in performing tasks.

5.4.3 Discussion

Investigating the three models has led us to conduct one-way ANOVA tests to see if the Optimistic, Basic, and Pessimistic models had significantly different impacts on the three performance measures. Since we implemented varying management cycle time while fixing manufacturing cycle time with these three models, we expected to find significant differences in organizational performance as suggested by Hill (1994). However, as the results presented in Table 5.12 indicate that almost tenfold improvement in management cycle time from the Pessimistic to the Optimistic models did not make a significant difference for the financial measure (*FM*) with unpartitionable sequential tasks (UNPSEQ) in stable and dynamic environments, as well as with reciprocal tasks (RECIP) in dynamic environments. In addition, the *OSTDV* and the *PSTDV* with unpartitionable sequential tasks in dynamic environments, and the *PSTDV* with partitionable sequential tasks did not show significant differences in performance in dynamic environments. Therefore, the reaction rate (*1/k*) which was identified as the major determinant of model behavior is put under scrutiny in the next section.

Optimistic/Basic/Pessimistic Models			
	Environments	Stable	Dynamic
	Dep. Var.	F Prob.	F Prob.
Unpartitionable Sequential Tasks (UNPSEQ)	*FM*	**0.0023**	**0.0111**
	OSTDV	-	**0.1046**
	PSTDV	0.0000	**0.0152**
Partitionable Sequential Tasks (PSEQ)	*FM*	0.0000	0.0000
	OSTDV	-	0.0000
	PSTDV	**0.0018**	0.0000
Reciprocal Tasks (RECIP)	*FM*	0.0000	**0.0796**
	OSTDV	-	0.0000
	PSTDV	0.0000	0.0000

Table 5.12 Results of one-way ANOVA tests for three Models

5.5 Final Experiment

With the first experiment, the reaction rate (*1/k*) relative to the management cycle time was identified as the major determinant of model behavior and thus we made an appropriate modification for the rate for the organic management control system. However, when we set up the three models (i.e. the Optimistic, Basic, and Pessimistic models) for testing effects of varying management cycle time while fixing manufacturing cycle time, we failed to implement an appropriate adjustment for reaction rates in each model.

The reaction rates were set for an acceptable behavior of manufacturing organizations in the Basic model with respect to the management cycle times. In the Optimistic model, the management cycle time of both the mechanistic and organic management control systems were improved; however, the reaction rates for both did not reflect the changes in the management cycle time (i.e. needed less responsive reaction rates since management can react faster). On the contrary in the Pessimistic model, the management cycle time of both the mechanistic and organic management control systems were slowed down; however, the reaction rates for both again did not reflect the changes in the management cycle time (i.e. needed more responsive reaction rates since management reacts slower). Therefore, in order to correct this fixed reaction rate relative to varying management cycle time in different models, the following changes in the models were implemented for this experiment.

Reaction Rate vs. Management Cycle Time

Since the management cycle time was manipulated by the delay parameter (i.e. dp), it was determined to find a relationship between an independent variable dp and a dependent variable k. Assuming that there is a negative linear relationship between dp and k, a k value of 1.5 when dp = 0.25/weeks is already determined from the basic manufacturing units with the mechanistic management control system. Furthermore, it is assumed that k is 2.5 for the manufacturing with mechanistic management control system when dp = 0.0275/weeks (which is the dp for the Optimistic model.). Using these two sets of k and dp, an y-intercept = 2.62 and a slope = -1/0.2225 are determined on a x-y plane where the x-axis represents dp and the y-axis represents k (see Figure 5.1). From this, we can extrapolate a k value for any dp. A k value is 1.3 for the manufacturing with mechanistic management control system when dp = 0.294/weeks in the Pessimistic model. The following equation is used to determine k_{new}.

$$k_{new} = (k_{old}/1.5) * [2.62-(dp/0.2225)]$$

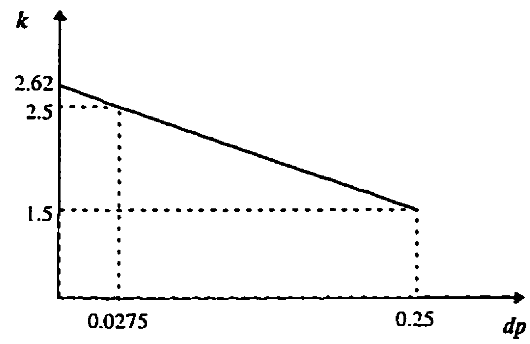


Figure 5.1 The relationship between *dp* and *k*

The term $(k_{old}/1.5)$ is multiplied by the intermediate result of $[2.62-(dp/0.2225)]$ to determine k_{new} in proportion of 1.5 and with respect to the fixed k_{old} values which were determined for the mechanistic and organic management control systems for the second experiment. Therefore, the following Table 5.13 summarizes the new *reaction rates*.

		Optimistic Model	*Middle Model**	*Basic Model*	*Pessimistic Model*
Mechanistic		1/2.5	1/2.0	1/1.5	1/1.3
Organic	if $TI_t - I_t > OR/3$	1/13.3	1/10.4	1/8	1/6.9
	if $0 < Ti_t - I_t \le OR/3$	1/2.5	1/2.0	1/1.5	1/1.3
	if $TI_t - I_t \le 0$	1/8.3	1/6.5	1/5	1/4.3

Note: Middle Model* instead of the Basic model is tested in the final experiment.

Table 5.13 Summary of the new *reaction rates (1/k)*

Coordination Effect

For extended enterprises performing reciprocal tasks, *coordination effect* process entities were set up between two supply chains. *Coordination effect*, which is expressed in terms of additional time delay, represents higher costs of reciprocal tasks coordination than either unpartitionable or partitionable sequential tasks coordination. Previously, we used a fixed *coordination effect* in terms of time which was determined with *dp* of 0.25 across the Optimistic, Basic, and Pessimistic models. However, it is assumed that as management cycle time (which is a dependent variable of *dp*) within a manufacturing unit is improved, the *coordination effect* in terms of time between two manufacturing units would also be improved. Therefore, we implemented a varying *coordination effect* according to changes in the management cycle time across three different models with distinct management cycle times.

It is assumed that there is a positive relationship between the management cycle time and the *coordination effect*, thus the *coordination effect* in terms of time is multiplied by *dp/0.25* to determine new *coordination effect*. The following equation was used to reflect varying *coordination effect* with respect to the management cycle time.

$$[N * (N-1)/2] * \{1/[TN * (TN-1)/2]\} * (dp/0.25), \qquad N \leq TN$$

where N = a number of partners in reciprocal tasks coordination
TN =Total number of manufacturing firms in an Extended Enterprise
dp = time delay parameter

Middle Model instead of the Basic Model

Instead of testing the Basic model, the Middle mode was tested in the subsequent experiment. Since the management cycle time of the Basic model is not much different from the management cycle time of the Pessimistic model, we created a model in which the management cycle time is in between the ones of the Optimistic and Pessimistic models. Therefore, the *dp* of 0.147 weeks was used to set up the Middle model for the subsequent experiment.

The Experiment

With the modification made in the models and experiment settings, the final set of experiments was performed. For each of the 48 experimental factor settings, 50 cases of experiment results were collected for a total of 2,400 cases of experiment. Furthermore, each set of 2,400 experiments was replicated with three different time delay parameters in order to examine the effect of varying management cycle time of the management function, while fixing manufacturing cycle time of the production function. These three sets of 2,400 experiments are referred to as the Optimistic, Middle, and Pessimistic models.

The delay parameter (*dp*) was set to be 0.0275, 0.147, and 0.294 weeks for the Optimistic, Middle, and Pessimistic models respectively. Therefore, the Pessimistic model for the manufacturing unit with the mechanistic management control system was set according to the survey by La Londe and Zinszer (1976), and the order cycle of the manufacturing entity with the mechanistic management control system in the Optimistic model was set to be under 24 hours. The order cycle of the manufacturing entity with the mechanistic management control system in the Middle model was set to be between one and 10.3 days.

However, the original *DT* (Delta Time) setting of 0.25 weeks resulted in the manufacturing cycle time of the three models to be constant, while the management cycle time of the management function varied in proportion to the delay parameter (*dp*). Therefore, comparison of the results of these three models allow us to examine the effect of varying management cycle time of the management function, while fixing manufacturing cycle time. The Optimistic, Middle, and Pessimistic models of the manufacturing unit with the organic management control system were arranged using the same delay parameter (*dp*) variables used in each respective case of the mechanistic ones. Table 5.14 summarizes three (revised) order cycle.

		Optimistic Model artificial delay (*dp*): 0.0275 weeks	**Middle Model artificial delay (*dp*): 0.147 weeks**	**Pessimistic Model artificial delay (*dp*): 0.294 weeks**
Mechanistic	MgmtCT	0.5775 day (0.0825 weeks)	3.087 days (0.441 weeks)	6.174 days (0.8820 weeks)
	MfgCT	3.5 days (0.5 weeks)	3.5 days (0.5 weeks)	3.5 days (0.5 weeks)
	Total OCT	**4.078 days (0.5825 weeks)**	**6.587 days (0.941 weeks)**	**9.674 days (1.382 weeks)**
Organic	MgmtCT	0.1925 day (0.0275 weeks)	1.029 day (0.147 weeks)	2.05 days (0.294 weeks)
	MfgCT	3.5 days (0.5 weeks)	3.5 days (0.5 weeks)	3.5 days (0.5 weeks)
	Total OCT	**3.693 days (0.5275 weeks)**	**4.529 days (0.647 weeks)**	**5.558 days (0.794 weeks)**

Note: •MgmtCT stands for management cycle time and MfgCT stands for manufacturing cycle time.
•OCT stands for order cycle time.
•7 working days a week.
•Delay is a parameter variable which manipulates the order cycle of individual manufacturing unit.

Table 5.14 Description of three sets of order cycle time

	Optimistic	Middle	Pessimistic
Number of factor settings	48	48	48
Number of replications per factor setting	50	50	50
Total number of cases	2,400	2,400	2,400
Total number of periods (*T*)	54 weeks	54 weeks	54 weeks
Total number of individual manufacturing units (*N*)	2 or 4	2 or 4	2 or 4
Customer Demand			
Base Level (*CBL*)	4,000 units/week	4,000 units/week	4,000 units/week
Environments (*2 levels*)			
Stable	-50% to +50% of base	-50% to +50% of base	-50% to +50% of base
Dynamic	-100% to +600% of base	-100% to +600% of base	-100% to +600% of base
Delay Parameter (*dp*)	0.0275 weeks	0.147 weeks	0.294 weeks
Management Cycle Time			
Mechanistic	0.0825 weeks	0.441 weeks	0.882 weeks
Organic	0.0275 weeks	0.147 weeks	0.294 weeks
Manufacturing Cycle Time			
Mechanistic	0.50 weeks	0.50 weeks	0.50 weeks
Organic	0.50 weeks	0.50 weeks	0.50 weeks
Reaction Rate (*1/k*)			
Mechanistic	1/2.5	1/2.0	1/1.3
Organic	1/13.3, if $TI_t - I_t > OR/3$	1/10.4, if $TI_t - I_t > OR/3$	1/6.9, if $TI_t - I_t > OR/3$
	1/2.5, if $0 < TI_t - I_t \leq OR/3$	1/2.0, if $0 < TI_t - I_t \leq OR/3$	1/1.3, if $0 < TI_t - I_t \leq OR/3$
	1/8.3, if $TI_t - I_t \leq 0$	1/6.5, if $TI_t - I_t \leq 0$	1/4.3, if $TI_t - I_t \leq 0$
Cost of Inventory/week (C_I)	\$0.50/week	\$0.50/week	\$0.50/week
Cost of Backlog/week (C_B)	\$1.00/week	\$1.00/week	\$1.00/week

Table 5.15 Summary of the final experiment settings

Each experiment was again performed over a period of 54 simulated weeks. -50% to +50% fluctuation of customer demand base level (*CBL:* 4,000 units/week) was assumed to simulate stable environments, while -100% to +600% fluctuation of *CBL* was assumed to simulate dynamic environments in this experiment. In addition, the reaction rates (*1/k*) are modified as discussed. Table 5.15 summarizes the final experiment settings.

5.5.1 Hypotheses Testing

Table 5.16 summarizes the results of the ANOVA hypotheses tests.

Models	*Dependent Variables*	*Independent Variables*			
		ENV **H_1** *p-value*	INTER **H_2** *p-value*	STRUCT **H_3** *p-value*	ENV x INTER **H_4** *p-value*
Optimistic Model	*FM*	0.000	0.000	0.000	0.000
	OSTDV	0.000	0.000	0.000	0.000
	PSTDV	0.000	0.000	**0.436**	0.000
Middle Model	*FM*	0.000	0.000	0.000	0.000
	OSTDV	0.000	0.000	0.000	0.000
	PSTDV	0.000	0.000	**0.007**	0.000
Pessimistic Model	*FM*	0.000	0.000	**0.093**	0.000
	OSTDV	0.000	0.000	0.000	0.000
	PSTDV	0.000	0.000	0.000	0.000

Note: •*FM* stands for financial measure.
•*OSTDV* represents deviation of order delivery time.
•*PSTDV* represents standard deviation of manufacturing cycle time.
•ENV stands for Environments.
•INTER represents interactions of management control systems.
•STRUCT stands for structure.
•ENV x INTER denotes interactions between ENV and INTER.

Table 5.16 Summary Results of ANOVA Tests of the final experiment

Hypothesis IV argued that there would be no significant interaction. As Table 5.16 reports, hypothesis IV was rejected for all three dimensions of performance measures across all three models. In other words, the particular combination of the factor levels of the all three factors does have significantly different impacts on the organizational performance.

Hypothesis I argued that different types of environments, which are stable and dynamic, would have no effect on the performance of an extended enterprise. The results of ANOVAs indicate that Hypothesis I was rejected for all three dimensions of performance measures across all three models as presented in Table 5.16. In other words, the results of experiments suggest that changes in environmental conditions have statistically significant effects on organizational performance of an extended enterprise.

Hypothesis II examined if alternative choices in types of interactions of the mechanistic and/or organic management control systems in extended enterprises would not make any difference in the performance of an extended enterprise. As the results presented in Table 5.16 indicate, hypothesis II was rejected as well for all three dimensions of performance measures across all three models as expected. These results imply very different organizational performance impacts of the different types of interactions of the mechanistic and/or organic management control systems on extended enterprises.

Hypothesis III argued that different structures of extended enterprises would have no effect on the performance of an extended enterprise. The results of the hypothesis III test indicated that conflicting results depending on performance measures across three models. Contrary to predictions, the production process measure (*PSTDV*) indicated that structures of an extended enterprises had no effect on the performance of an extended enterprise in the Optimistic and Middle models, while the financial measure (*FM*) of the Pessimistic model suggested that no effects of structures on the performance of an extended enterprise.

However, the overall results of these four hypotheses tests support our fundamental premises of this research that not only each contingent factor, but also the interaction among all three contingent factors has effect on organizational performance of an extended enterprise.

5.5.2 *Post Hoc* Analysis

One-way analysis of variance (ANOVA) with *post hoc* Scheffé multiple comparison tests was employed to identify effective or ineffective frameworks of management control systems for an extended enterprise operating within a particular combination of the contingent factors across the three models. Each model will be tested individually and the results of the Scheffé tests for the Optimistic model is discussed first.

5.5.2.1 Optimistic Model

The Optimistic model is described as a manufacturing organization where the management cycle time is significantly faster than the manufacturing cycle time. For manufacturing units with the mechanistic management control system, the management cycle time is 0.0825 weeks and the manufacturing cycle time is 0.50 weeks. On the other hand, for manufacturing units with the organic management control system, the management cycle time is 0.0275 weeks and the manufacturing cycle time is 0.50 weeks. Table 5.17 summarizes the results of the Scheffé tests of the Optimistic model.

Before preceding with analyses, notice that most of mean values of extended enterprises structured to perform the partitionable sequential tasks (i.e. PSEQ) and the reciprocal tasks (i.e. RECIP) are identical by frameworks. As the management cycle time of the *Management* function becomes faster relative to the manufacturing cycle time of the *Production* function, the *coordination effort* (or cost) in terms of time also becomes smaller and insignificant due to the assumption made in the discussion of coordination effect in Section 5.5. This results in identical organizational performance by frameworks in the PSEQ and the RECIP with the Optimistic Model.

As presented in Table 5.17, *FM* does not show significant differences with unpartitionable sequential tasks in stable environments. While in dynamic environments, the all mechanistic management control systems framework (i.e. 2MM) is the least effective with unpartitionable sequential tasks. However, all mechanistic management control systems frameworks (i.e. SMMMM and RMMMM) are the most effective frameworks with the partitionable sequential and reciprocal tasks in stable environments. Furthermore, although there are no statistical differences, management control systems frameworks with dominantly mechanistic management control systems organized near the customer are identified to be more effective with partitionable sequential and reciprocal tasks in dynamic environments. On the other hand, the frameworks with all organic management control systems (i.e. SOOOO and ROOOO) are the least effective for the *FM* with the partitionable sequential and reciprocal tasks in both stable and dynamic environments.

Final Experiment: Optimistic Model												
Dependent Var.	FM				OSTDV				PSTDV			
Environment	Stable		Dynamic		Stable		Dynamic		Stable		Dynamic	
	Mean	Grp	Mean	Grp	Mean	Grp	Mean	Grp	Mean	Grp	Mean	Grp
Unpartitionable sequential tasks	*F = 0.0170*		*F=0.0001*		-		*F=0.1284*		*F=0.0250*		*F=0.0001*	
2MM	650,627	n/a	*1,373,993*	*b*	.0000	n/a	.1902	n/a	*.3210*	n/a	*2.6906*	*b*
2MO	**645,897**		1,263,084	a	.0000		**.1738**		.2698		2.4234	a
2OM	*654,553*		**1,209,819**	a	.0000		*.1970*		.2654		**2.2064**	a
2OO	*648,289*		1,217,947	a	.0000		.1970		**.2480**		2.3586	a
Partitionable sequential tasks	*F=0.0000*		*F=0. 0007*		-		*F=0.3766*		*F=0.0000*		*F=0.1016*	
SMMMM	**709,820**	a	1,410,448	n/a	.0000	n/a	.0268	n/a	**.4312**	a	1.9696	n/a
SMMMO	724,235	b	**1,399,822**		.0000		.0186		.8130	c	1.9430	
SMMOM	721,553	b	1,424,132		.0000		*.0376*		.6274	b	1.9460	
SMMOO	737,221	c	1,454,487		.0000		.0278		1.2686	d	*1.9964*	
SMOMO	740,943	d	1,459,680		.0000		**.0070**		.8160	c	1.7954	
SMOOM	737,984	c	1,475,839		.0000		.0246		.8100	c	1.7988	
SOMOM	733,002	c	1,436,871		.0000		.0210		.6320	b	**1.7680**	
SOOMO	754,658	f	1,526,370		.0000		.0152		1.2660	d	1.9082	
SOOOM	747,778	e	1,479,629		.0000		.0214		1.2726	d	1.8546	
SOOOO	*764,051*	*g*	*1,566,794*		.0000		.0086		*1.2736*	*d*	1.8130	
Reciprocal tasks	*F=0.0000*		*F=0.0007*		-		*F=0.3771*		*F=0.0000*		*F=0.0970*	
RMMMM	**709,820**	a	1,410,448	n/a	.0000	n/a	.0268	n/a	**.4312**	a	1.9696	n/a
RMMMO	724,235	b	**1,399,822**		.0000		.0186		.8130	c	1.9430	
RMMOM	721,556	b	1,424,256		.0000		*.0376*		.6274	b	1.9456	
RMMOO	736,346	b	1,451,507		.0000		.0278		1.2670	d	*1.9996*	
RMOMO	740,943	c	1,459,680		.0000		**.0070**		.8160	c	1.7954	
RMOOM	737,984	b	1,475,839		.0000		.0246		.8100	c	1.7988	
ROMOM	733,002	b	1,436,871		.0000		.0210		.6320	b	**1.7680**	
ROOMO	754,658	e	1,526,370		.0000		.0152		1.2660	d	1.9082	
ROOOM	747,778	d	1,479,629		.0000		.0214		1.2726	d	1.8546	
ROOOO	*764,051*	*f*	*1,566,794*		.0000		.0086		*1.2736*	*d*	1.8130	

Table 5.17 Results of the Scheffé tests for the Optimistic Model: Final Experiment

In fact, this result demonstrates the presence of "system nervousness" (Orlicky, 1975) with the management control systems frameworks with all organic management control systems (i.e. 2OO, SOOOO, and ROOOO). "System nervousness" is a term that describes an unstable system which constantly attempts to update its state faster than it is able to respond and therefore may never be able to stabilize in one state due to delays in processing the inputs. Therefore, the management control systems frameworks with all organic management control systems lead an extended enterprise to become nervous and result in poor organizational performance.

However, as the results in Table 5.17 indicate that the management control systems framework with all organic management control systems with the unpartitionable sequential tasks (i.e. 2OO) is not identified as the least effective. Since a single supply chain structured to perform unpartitionable sequential tasks (UNPSEQ) manages the same amount of work that two supply chains of extended enterprises structured to perform partitionable sequential tasks (PSEQ) would manage, the single supply chain of UNPSEQ is inherently slow to react to changes in inputs. Thus, "system nervousness" is prevented from occurring for extended enterprises structured to perform the unpartitionable sequential tasks when it occurs with partitionable sequential and/or reciprocal tasks under the same condition.

In order to confirm this assumption, we performed simulation runs with the 2MM and 2OO under the same experiment setting (in stable environments) except that the 2MM and 2OO managed only half the customer orders that they originally managed (thus the single supply chains in the 2MM and 2OO managed the same amount of work that each of the two supply chains of such as the SMMMM and SOOOO managed). The result indicated that the assumption was a sound one since the 2OO (mean = $382,977) became statistically less effective than the 2MM (mean = $355,428) in this sub-experiment.

The measure of delivery (*OSTDV*) does not show significant differences among different frameworks of management control systems across all three structures of extended enterprises in both stable and dynamic environments.

PSTDV identifies that the framework of all mechanistic systems (i.e. 2MM) to be the least effective to keep the production flow smooth in stable and dynamic environments with unpartitionable sequential tasks (see Table 5.16). However, with partitionable sequential and reciprocal tasks in stable environments, all mechanistic frameworks (i.e. SMMMM and RMMMM) are the most effective management control systems framework to keep the production flow smooth, while all organic management control systems framework (i.e. SOOOO and ROOOO) are the least effective.

Although no statistical differences are found, the management control systems frameworks with more responsive organic management control systems become viable to help extended enterprises to keep its production flow relatively smoother than the frameworks with less responsive mechanistic management control systems as environments become dynamic. However, the 2MM is more effective than 2OO for the *PSTDV* only when the fluctuation coming from the customer is very small as discussed in Section 5.4.2.1.

5.5.2.2 Middle Model

The Middle model can be described as a manufacturing organization with the mechanistic management control system where the management cycle time is more or less similar to the manufacturing cycle time. For manufacturing units with the mechanistic management control system, the management cycle time is 0.441 weeks and the manufacturing cycle time is 0.50 weeks. For manufacturing units with the organic management control system, the management cycle time is 0.147 weeks and the manufacturing cycle time is 0.50 weeks. Table 5.18 summarizes the results of the Scheffé tests for the Middle model.

Final Experiment: Middle Model												
Dependent Var.	FM				OSTDV				PSTDV			
Environment	Stable		Dynamic		Stable		Dynamic		Stable		Dynamic	
	Mean	Grp	Mean	Grp	Mean	Grp	Mean	Grp	Mean	Grp	Mean	Grp
Unpartitionable sequential tasks	***F = 0.0000***		***F=0.0000***		.		***F=0.8810***		***F=0.0000***		***F=0.0000***	
2MM	*696,484*	*c*	*1,964,003*	*b*	.0000	n/a	.1902	n/a	*.6730*	*c*	*4.4694*	*c*
2MO	648,206	a	1,571,981	a	.0000		**.1738**		.3686	b	3.2272	b
2OM	652,923	b	1,473,033	a	.0000		*.1970*		.3724	b	2.6698	a
2OO	**635,244**	**a**	**1,430,122**	**a**	.0000		*.1970*		**.2552**	**a**	**2.6368**	**a**
Partitionable sequential tasks	***F=0.0000***		***F=0.0000***		.		***F=0.0000***		***F=0.0000***		***F=0.0000***	
SMMMM	*750,550*	*b*	*1,957,131*	*b*	.0000	n/a	.0802	a	.5698	a	3.1066	b
SMMMO	747,479	b	1,845,456	a	.0000		*.0852*	*a*	.7382	b	*3.1176*	*b*
SMMOM	737,788	a	1,808,473	a	.0000		.0842	a	.5832	a	3.1066	b
SMMOO	744,731	a	1,841,738	a	.0000		.0804	a	*1.0018*	*c*	3.1066	b
SMOMO	744,408	a	1,733,780	a	.0000		.0498	a	.7090	b	2.1258	a
SMOOM	734,921	a	1,698,409	a	.0000		.0596	a	.7090	b	2.1492	a
SOMOM	**725,434**	**a**	**1,663,039**	**a**	.0000		.0228	a	**.4678**	**a**	1.9376	a
SOOMO	743,667	a	1,746,666	a	.0000		.0718	a	*1.0018*	*c*	2.2214	a
SOOOM	732,172	a	1,694,692	a	.0000		.0228	a	*1.0018*	*c*	2.0066	a
SOOOO	738,911	a	1,726,344	a	.0000		**.0146**	**a**	*1.0018*	*c*	**1.8654**	**a**
Reciprocal tasks	***F=0.0000***		***F=0.0000***		.		***F=0.0000***		***F=0.0000***		***F=0.0000***	
RMMMM	*750,550*	*b*	*1,957,131*	*b*	.0000	n/a	.0802	a	.5698	a	3.1066	b
RMMMO	747,479	b	1,845,456	a	.0000		*.0852*	*a*	.7382	b	*3.1176*	*b*
RMMOM	737,992	a	1,810,085	a	.0000		.0844	a	.5842	a	3.1092	b
RMMOO	744,527	a	1,840,125	a	.0000		.0802	a	*1.0018*	*c*	3.0980	b
RMOMO	744,408	a	1,733,780	a	.0000		.0498	a	.7090	b	2.1258	a
RMOOM	734,921	a	1,698,409	a	.0000		.0596	a	.7090	b	2.1492	a
ROMOM	**725,434**	**a**	**1,663,039**	**a**	.0000		.0228	a	**.4678**	**a**	1.9376	a
ROOMO	743,667	a	1,746,666	a	.0000		.0718	a	*1.0018*	*c*	2.2214	a
ROOOM	732,172	a	1,694,692	a	.0000		.0228	a	*1.0018*	*c*	2.0066	a
ROOOO	738,911	a	1,726,344	a	.0000		**.0146**	**a**	*1.0018*	*c*	**1.8654**	**a**

Table 5.18 Results of the Scheffé tests for the Middle Model: Final Experiment

Again before preceding with analyses of the Middle model, notice that most of mean values of extended enterprises structured to perform the partitionable sequential tasks (i.e. PSEQ) and the reciprocal tasks (i.e. RECIP) are again similar as the results presented in Table 5.18. As the management cycle time of the *Management* function becomes faster relative to the manufacturing cycle time of the *Production* function, the *coordination effort* (or cost) in terms of time also becomes smaller and insignificant due to the assumption made in the discussion of coordination effort in Section 5.5. This results in identical organizational performance between the PSEQ and the RECIP.

The financial measure (*FM*) indicates that all mechanistic management control systems frameworks (i.e. 2MM, SMMMM, and RMMMM) to be the least effective frameworks across all three structures of extended enterprises in both stable and dynamic environments. *FM* also identifies a group of management control systems frameworks to be statistically effective frameworks within each of the three structures of extended enterprises in stable and dynamic environments; however while the difference is not statistically significant, 2OO, SOMOM, and ROMOM are appeared to be the most effective for the *FM* within each structure in stable and dynamic environments.

The measure of delivery (*OSTDV*) does not show significant differences among different frameworks of management control systems across all three structures of extended enterprises in both stable and dynamic environments.

The measure of smoothness of production flow (*PSTDV*) indicates that all mechanistic management control systems frameworks (i.e. 2MM) to be the least effective framework with unpartitionable sequential tasks in stable and dynamic environments. On the other hand, the 2OO is the most effective.

The *PSTDV* identifies all organic management control systems frameworks (i.e. SOOOO and ROOOO) to be one of less effective frameworks to keep production flow smooth, while all mechanistic management control systems (i.e. SMMMM and RMMMM) to be more effective frameworks in the stable environment with partitionable sequential and reciprocal tasks. However in the dynamic environment, the *PSTDV* identifies all organic frameworks (i.e. SOOOO and ROOOO) to be more effective, while all mechanistic frameworks (i.e. SMMMM and RMMMM) to be less effective frameworks with partitionable sequential and reciprocal tasks. As discussed in Section 5.4.2.1, the management control systems frameworks with all mechanistic frameworks (i.e. 2MM, SMMMM, and RMMMM) can help an extended enterprise to keep its production flow smoother than the all organic frameworks (i.e. 2OO, SOOOO, and ROOOO) only when the fluctuation coming from the customer is very small (in other words, when the external environment is very stable). However, the 2MM is identified as the least effective, but the 2OO is identified as the most effective for the *PSTDV* in the stable environment because a single supply chain inherently faces with a relatively more dynamic environment than two supply chains even in the stable environment. Therefore, when the external environments become dynamic, the management control systems frameworks with all organic management control systems become more effective to keep production flow smoother than the all mechanistic management control systems frameworks.

5.5.2.3 Pessimistic Model

The Pessimistic model can be described as a manufacturing organization with the mechanistic management control system where the management cycle time is slower than the manufacturing cycle time. For manufacturing units with the mechanistic management control system in the Pessimistic model, the management cycle time is 0.882 weeks and the manufacturing cycle time is 0.50 weeks. For manufacturing units with the organic management control system, the management cycle time is 0.294 weeks and the manufacturing cycle time is 0.50 weeks. Table 5.19 summarizes the results of the Scheffé tests for the Pessimistic model.

Please notice that since the *coordination effort* (or cost) in terms of time becomes larger and significant with a relatively large management cycle time, the PSEQ and the RECIP resulted in different organizational performance in this experiment setting.

Final Experiment: Pessimistic Model												
Dependent Var.	FM				OSTDV				PSTDV			
Environment	Stable		Dynamic		Stable		Dynamic		Stable		Dynamic	
	Mean	Grp	Mean	Grp	Mean	Grp	Mean	Grp	Mean	Grp	Mean	Grp
Unpartitionable sequential tasks	***F = 0.0000***		***F=0.0000***		-		***F=0.3202***		***F=0.0000***		***F=0.0000***	
2MM	*794,856*	*c*	*2,742,088*	*c*	.0000	n/a	*.1944*	n/a	*.9990*	*b*	*6.6266*	*c*
2MO	692,144	b	2,062,131	b	.0000		.1798		.4766	a	4.3354	c
2OM	675,783	a	1,830,210	a	.0000		.1904		.4224	a	3.2320	b
2OO	**649,980**	**a**	**1,739,488**	**a**	.0000		**.1788**		**.2834**	**a**	**3.1934**	**a**
Partitionable sequential tasks	***F=0.0000***		***F=0.0000***		-		***F=0.0417***		***F=0.0000***		***F=0.0000***	
SMMMM	*830,069*	*d*	*2,676,272*	*d*	.0000	n/a	.0480	n/a	.7292	b	*4.4462*	*b*
SMMMO	801,704	c	2,430,332	c	.0000		*.0482*		.8028	b	*4.4462*	*b*
SMMOM	781,058	b	2,319,352	b	.0000		.0470		.7202	b	4.3976	b
SMMOO	780,051	a	2,323,675	b	.0000		.0480		*.8066*	*b*	*4.4462*	*b*
SMOMO	773,338	a	2,186,393	a	.0000		.0320		.6276	a	2.8032	a
SMOOM	754,057	a	2,081,762	a	.0000		.0362		.6304	a	2.8566	a
SOMOM	734,775	a	1,977,132	a	.0000		.0158		**.4050**	**a**	2.3642	a
SOOMO	755,131	a	2,099,416	a	.0000		.0382		.7860	b	2.9780	a
SOOOM	732,404	a	1,974,105	a	.0000		.0158		.7478	b	2.4502	a
SOOOO	**730,033**	**a**	**1,971,078**	**a**	.0000		**.0122**		.7478	b	**2.2384**	**a**
Reciprocal tasks	***F=0.0000***		***F=0.0000***		-		***F=0.6065***		***F=0.0000***		***F=0.0000***	
RMMMM	*864,414*	*d*	*2,778,986*	*e*	.0000	n/a	.0600	n/a	*1.0934*	*b*	*5.1708*	*b*
RMMMO	824,023	d	2,479,448	d	.0000		*.0664*		*1.0934*	*b*	*5.1708*	*b*
RMMOM	800,369	c	2,396,352	c	.0000		.0644		*1.0934*	*b*	*5.1708*	*b*
RMMOO	790,963	c	2,336,801	b	.0000		.0646		1.0838	b	5.1418	b
RMOMO	783,631	b	2,179,909	a	.0000		.0514		.6848	a	3.1444	a
RMOOM	759,977	a	2,096,814	a	.0000		.0608		.7030	a	3.1738	a
ROMOM	736,323	a	2,013,718	a	.0000		**.0396**		**.5220**	**a**	2.7212	a
ROOMO	753,145	a	2,051,195	a	.0000		.0642		.7658	a	3.2238	a
ROOOM	729,109	a	1,962,286	a	.0000		.0400		.6374	a	2.7212	a
ROOOO	**721,894**	**a**	**1,910,853**	**a**	.0000		.0400		.6282	a	**2.4516**	**a**

Table 5.19 Results of the Scheffé tests for the Pessimistic Model: Final Experiment

The financial measure (*FM*) indicates that all mechanistic management control systems frameworks (i.e. 2MM, SMMMM, and RMMMM) to be the least effective frameworks across all three structures of extended enterprises in both stable and dynamic environments (see Table 5.19). *FM* also identifies a group of management control systems frameworks to be statistically effective frameworks within each of the three structures of extended enterprises in stable and dynamic environments. While the difference is not statistically significant, all organic management control systems frameworks (i.e. 2OO, SOOOO, and ROOOO) appear to be more effective frameworks for the *FM* across all three structures of extended enterprises in both stable and dynamic environments.

OSTDV does not show significant differences among different frameworks of management control systems across all three structures of extended enterprises in both stable and dynamic environments. In fact, in stable environments, the results indicate that all frameworks of management control systems can help an extended enterprise satisfy customer orders without having any backlog orders. While the differences among the *OSTDV*s of different management control systems frameworks with the extended enterprises structured to perform the unpartitionable sequential tasks in dynamic environments are small, no statistical difference is found. Interestingly, the ANOVA test exhibits significant differences at $\alpha = 0.0001$ among different management control systems frameworks with extended enterprises structured to perform the partitionable sequential and reciprocal tasks in dynamic environments for the *OSTDV*; however, the Scheffé tests indicate that all pairs of means are not significantly different at $\alpha = 0.05$.

The measure of smoothness of production flow (*PSTDV*) indicates that all mechanistic management control systems frameworks (i.e. 2MM, SMMMM, and RMMMM) to be least effective with all three structures of extended enterprises in stable and dynamic environments.

Additional Scheffé tests were performed to further explore the results of the hypothesis III test. The results of main Scheffé tests in Tables 5.17, 5.18, and 5.19 identified effective (or ineffective) frameworks of management control systems for an extended enterprise operating within a particular combination of environments and types of interactions of management control systems separately in three possible structures of extended enterprises (i.e. unpartitionable sequential, partitionable sequential, and reciprocal structures). Thus, the Table 5.20 reports the results of Scheffé tests which compare the relative effectiveness of three structures of extended enterprises on the organizational performance in each model.

With the financial measure (*FM*), the structure of extended enterprises has an impact on the organizational performance and the unpartitionable sequential structure (UNPSEQ) as a more effective structure for both stable and dynamic environments across all three models.

The measure of delivery (*OSTDV*) did not show any significant differences among different frameworks of management control systems across all three structures of extended enterprises in stable environments. In fact, in stable environments, the results indicate that all three extended enterprise structures can help an extended enterprise satisfy customer orders without backlog. However with all three models in dynamic environments, significant differences were found among different structures and the PSEQ was the most effective structure, while the UNPSEQ was least effective.

With the measure of production process (*PSTDV*), the partitionable sequential structure (PSEQ) was the most effective structure, while the least effective one was the unpartitionable sequential structure (UNPSEQ) in the dynamic environment. However in the stable environment, the UNPSEQ was the most effective structure contrary to the prediction as discussed in Section 5.4.2.3.

Additional Scheffé tests for the Final Experiment												
Dependent Var.	FM				OSTDV				PSTDV			
Environment	Stable		Dynamic		Stable		Dynamic		Stable		Dynamic	
Structure	Mean	Grp	Mean	Grp	Mean	Grp	Mean	Grp	Mean	Grp	Mean	Grp
Optimistic Model	***F=0.0000***		***F=0.0000***		-		***F=0.0000***		***F=0.0000***		***F=0.0000***	
UNPSEQ	649,842	a	1,266,211	a	0.0000	n/a	.1895	b	.2760	a	2.4197	b
PSEQ	737,125	b	1,463,407	b	0.0000		.0209	a	.9210	b	1.8793	a
RECIP	737,037	b	1,463,122	b	0.0000		.0209	a	.9209	b	1.8796	a
Middle Model	***F=0.0000***		***F=0.0000***		-		***F=0.0000***		***F=0.0000***		***F=0.0000***	
UNPSEQ	658,214	a	1,609,785	a	0.0000	n/a	.1950	b	.4173	a	3.2508	b
PSEQ	740,006	b	1,771,573	b	0.0000		.0571	a	.7784	b	2.4737	a
RECIP	740,006	b	1,771,573	b	0.0000		.0571	a	.7785	b	2.4737	a
Pessimistic Model	***F=0.0000***		***F=0.0060***		-		***F=0.0000***		***F=0.0000***		***F=0.0000***	
UNPSEQ	703,191	a	2,093,479	a	0.0000	n/a	.1859	c	.5454	a	4.3469	c
PSEQ	767,262	b	2,204,052	b	0.0000		.0341	a	.7003	b	3.3427	a
RECIP	776,385	b	2,220,636	b	0.0000		.0551	b	.8305	c	3.8011	b

Note:
- UNPSEQ stands extended enterprises structured to perform for the unpartitionable sequential tasks
- PSEQ stands for extended enterprises structured to perform the partitionable sequential tasks
- RECIP denotes for extended enterprises structured to perform the reciprocal tasks

Table 5.20 Results of the additional Scheffé tests for the Final Experiment

5.5.3 Discussion

The final experiment was conducted mainly because the results of the second experiment's one-way ANOVA tests to see if the Optimistic, Basic, and Pessimistic models had significantly different impacts on the three dimensions of performance. Thus, we conducted the same one-way ANOVA tests to see if the Optimistic, Middle, and Pessimistic models had significantly different impacts on the three performance measures. The Table 5.21 summarizes the results of the ANOVA. The results indicate that overall the three models had significantly different impacts on the three dimensions of performance (except for the *OSTDV* in dynamic environments with extended enterprises structured to perform the unpartitionable sequential tasks), as we expected.

Optimistic/Basic/Pessimistic Models			
	Environments	Stable	Dynamic
	Dep. Var.	F Prob.	F Prob.
Unpartitionable Sequential Tasks (UNPSEQ)	*FM*	0.0000	0.0000
	OSTDV	-	**0.2578**
	PSTDV	0.0000	0.0000
Partitionable Sequential Tasks (PSEQ)	*FM*	0.0000	0.0000
	OSTDV	-	0.0000
	PSTDV	0.0000	0.0000
Reciprocal Tasks (RECIP)	*FM*	0.0000	0.0000
	OSTDV	-	0.0000
	PSTDV	0.0000	0.0000

Table 5.21 Results of one-way ANOVA tests for three Models

5.6 Summary

For all three sets of experiments, the results of hypotheses tests I through IV supported the fundamental premises of this research. Furthermore, the results of *post hoc* multiple comparisons using Scheffé tests identified effective and ineffective groups of management control systems frameworks for an extended enterprise operating within a specific combination of contingent factors.

Tables 5.22 to 5.28 present the most and the least effective groups of management control systems frameworks within each experiment model of the three sets of experiments. Individual columns represent a specific combination of contingent factors and "n/a" in a column represents a situation where no two frameworks are significantly different statistically.

FIRST EXPERIMENT																	
EFFECTIVE GROUPS																	
Stable Environments									Dynamic Environments								
UNPSEQ			PSEQ			RECIP			UNPSEQ			PSEQ			RECIP		
fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv
mo	mo	mo	mmmm	n/a	mmmo	n/a	n/a	mmoo	om	mo	mo	mmmm	mmom	mmmo	n/a	mmmo	mmmo
om	om	om	mmmo		mmom			momo		om	om	mmmo	mmoo	mmom		mmom	mmom
	oo	oo	mmom		mmoo			moom		oo	oo	mmom	momo	momo		mmoo	mmoo
			mmoo		momo			omom				mmoo	moom	moom		momo	momo
			momo		moom			oomo				momo	omom	omom		moom	moom
			moom		omom			ooom				moom	oomo	oomo		omom	omom
			omom		oomo			oooo				omom	ooom	ooom		oomo	oomo
			ooom		ooom							oomo	oooo	oooo		ooom	ooom
					oooo							ooom				oooo	oooo

INEFFECTIVE GROUPS																	
Stable Environments									Dynamic Environments								
UNPSEQ			PSEQ			RECIP			UNPSEQ			PSEQ			RECIP		
fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv
mm	mm	mm	oooo	n/a	mmmm	n/a	n/a	mmmm	mm	mm	mm	oooo	mmmm	mmmm	n/a	mmmm	mmmm
oo									mo		mo						
									oo								

Note: •UNPSEQ stands for unpartitionable sequential tasks, PSEQ stands for partitionable sequential tasks, & RECIP stands for reciprocal tasks.
•fm stands for financial measure, ostdv denoted for standard deviation of order delivery time, & pstdv standard deviation of manufacturing cycle time.
•First letter (i.e. 2, S, or R) from the names representing various extended enterprise models is omitted in the table to fit the table in one page.

Table 5.22 Summary of effective and ineffective frameworks of the First Experiment

SECOND EXPERIMENT: THE OPTIMISTIC MODEL																	
EFFECTIVE GROUP																	
Stable Environments									Dynamic Environments								
UNPSEQ			PSEQ			RECIP			UNPSEQ			PSEQ			RECIP		
fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv
mo om oo	n/a	mo om oo	n/a	n/a	mmmm mmmo mmom moom omom	mmoo moom omom oomo ooom oooo	n/a	mmmm mmmo mmom moom omom	mo om oo	n/a	om oo	n/a	n/a	mmmm mmoo momo moom omom oomo ooom oooo	mmmo mmom mmoo momo moom omom oomo ooom oooo	n/a	momo moom omom oomo ooom oooo
INEFFECTIVE GROUP																	
Stable Environments									Dynamic Environments								
UNPSEQ			PSEQ			RECIP			UNPSEQ			PSEQ			RECIP		
fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv
mm	n/a	mm	n/a	n/a	oooo	mmmm	n/a	oooo	mm	n/a	mm	n/a	n/a	mmmm	mmmm	n/a	mmmm

Note: •UNPSEQ stands for unpartitionable sequential tasks, PSEQ stands for partitionable sequential tasks, & RECIP stands for reciprocal tasks.
•fm stands for financial measure, ostdv denoted for standard deviation of order delivery time, & pstdv standard deviation of manufacturing cycle time.
•First letter (i.e. 2, S, or R) from the names representing various extended enterprise models is omitted in the table to fit the table in one page.

Table 5.23 Summary of effective and ineffective frameworks of the Second Experiment: the Optimistic Model

SECOND EXPERIMENT: THE BASIC MODEL																	
EFFECTIVE GROUPS																	
Stable Environments									Dynamic Environments								
UNPSEQ			PSEQ			RECIP			UNPSEQ			PSEQ			RECIP		
fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv
om	n/a	om	moom	n/a	mmom	moom	n/a	momo	mo	n/a	om	mmmo	n/a	momo	moom	n/a	momo
oo		oo	omom		momo	omom		moom	om		oo	mmom		moom	omom		moom
			oomo		moom	oomo		omom	oo			mmoo		omom	oomo		omom
			ooom		omom	ooom		oomo				momo		oomo	ooom		oomo
			oooo			oooo		ooom				moom		ooom	oooo		ooom
								oooo				omom		oooo			oooo
												oomo					
												ooom					
												oooo					

INEFFECTIVE GROUPS																	
Stable Environments									Dynamic Environments								
UNPSEQ			PSEQ			RECIP			UNPSEQ			PSEQ			RECIP		
fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv
mm	n/a	mm	mmmm	n/a	oooo	mmmm	n/a	mmmm	mm	n/a	mm	mmmm	n/a	mmmm	mmmm	n/a	mmmm

Note: •UNPSEQ stands for unpartitionable sequential tasks, PSEQ stands for partitionable sequential tasks, & RECIP stands for reciprocal tasks.
•fm stands for financial measure, ostdv denoted for standard deviation of order delivery time, & pstdv standard deviation of manufacturing cycle time.
•First letter (i.e. 2, S, or R) from the names representing various extended enterprise models is omitted in the table to fit the table in one page.

Table 5.24 Summary of effective and ineffective frameworks of the Second Experiment: the Basic Model

SECOND EXPERIMENT: THE PESSIMISTIC MODEL																	
EFFECTIVE GROUPS																	
Stable Environments									Dynamic Environments								
UNPSEQ			PSEQ			RECIP			UNPSEQ			PSEQ			RECIP		
fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv
mo	n/a	mo	mmom	n/a	mmom	momo	n/a	mmom	mo	n/a	om	mmmo	n/a	momo	mmom	n/a	momo
om	om	om	mmoo		moom	moom		momo	om		oo	mmom		moom	mmoo		moom
oo	oo	oo	momo		omom	omom		moom	oo			mmoo		omom	momo		omom
			moom			oomo		omom				momo		oomo	moom		oomo
			omom			ooom		oomo				moom		ooom	omom		ooom
			oomo			oooo		ooom				omom		oooo	oomo		oooo
			ooom									oomo			ooom		
			oooo									ooom			oooo		
												oooo					
INEFFECTIVE GROUPS																	
Stable Environments									Dynamic Environments								
UNPSEQ			PSEQ			RECIP			UNPSEQ			PSEQ			RECIP		
fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv
mm	n/a	mm	mmmm	n/a	oooo	mmmm	n/a	mmmm	mm	n/a	mm	mmmm	n/a	mmmm	mmmm	n/a	mmmm

Note: •UNPSEQ stands for unpartitionable sequential tasks, PSEQ stands for partitionable sequential tasks, & RECIP stands for reciprocal tasks.
•fm stands for financial measure, ostdv denoted for standard deviation of order delivery time, & pstdv standard deviation of manufacturing cycle time.
•First letter (i.e. 2, S, or R) from the names representing various extended enterprise models is omitted in the table to fit the table in one page.

Table 5.25 Summary of effective and ineffective frameworks of the Second Experiment: the Pessimistic Model

FINAL EXPERIMENT: THE OPTIMISTIC MODEL																	
EFFECTIVE GROUPS																	
Stable Environments									Dynamic Environments								
UNPSEQ			PSEQ			RECIP			UNPSEQ			PSEQ			RECIP		
fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv
n/a	n/a	n/a	mmmm	n/a	mmmm	mmmm	n/a	mmmm	mo om oo	n/a	mo om oo	n/a	n/a	n/a	n/a	n/a	n/a

INEFFECTIVE GROUPS																	
Stable Environments									Dynamic Environments								
UNPSEQ			PSEQ			RECIP			UNPSEQ			PSEQ			RECIP		
fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv
n/a	n/a	n/a	oooo	n/a	oomo ooom oooo	oooo	n/a	mmoo oomo ooom oooo	mm	n/a	mm	n/a	n/a	n/a	n/a	n/a	n/a

Note: •UNPSEQ stands for unpartitionable sequential tasks, PSEQ stands for partitionable sequential tasks, & RECIP stands for reciprocal tasks.
•fm stands for financial measure, ostdv denoted for standard deviation of order delivery time, & pstdv standard deviation of manufacturing cycle time.
•First letter (i.e. 2, S, or R) from the names representing various extended enterprise models is omitted in the table to fit the table in one page

. **Table 5.26 Summary of effective and ineffective frameworks of the Final Experiment: the Optimistic Model**

FINAL EXPERIMENT: THE MIDDLE MODEL																	
EFFECTIVE GROUPS																	
Stable Environments									Dynamic Environments								
UNPSEQ			PSEQ			RECIP			UNPSEQ			PSEQ			RECIP		
fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv
mo om	n/a	oo	mmom mmoo momo moom omom oomo ooom oooo	n/a	mmmm mmom omom	mmom mmoo momo moom omom oomo ooom oooo	n/a	mmmm mmom omom	mo om oo	n/a	om oo	mmmo mmom mmoo momo moom omom oomo ooom oooo	n/a	momo moom omom oomo ooom oooo	mmom mmoo momo moom omom oomo ooom oooo	n/a	momo moom omom oomo ooom oooo
INEFFECTIVE GROUP																	
Stable Environments									Dynamic Environments								
UNPSEQ			PSEQ			RECIP			UNPSEQ			PSEQ			RECIP		
fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv
mm	n/a	mm	mmmm mmmo	n/a	mmoo oomo ooom oooo	mmmm mmmo	n/a	mmoo oomo ooom oooo	mm	n/a	mm	mmmm	n/a	mmmm mmmo mmom mmoo	mmmm	n/a	mmmm mmmo mmom mmoo

Note: •UNPSEQ stands for unpartitionable sequential tasks, PSEQ stands for partitionable sequential tasks, & RECIP stands for reciprocal tasks.
•fm stands for financial measure, ostdv denoted for standard deviation of order delivery time, & pstdv standard deviation of manufacturing cycle time.
•First letter (i.e. 2, S, or R) from the names representing various extended enterprise models is omitted in the table to fit the table in one page.

. **Table 5.27 Summary of effective and ineffective frameworks of the Final Experiment: the Middle Model**

FINAL EXPERIMENT: THE PESSIMISTIC MODEL																	
EFFECTIVE GROUPS																	
Stable Environments									Dynamic Environments								
UNPSEQ			PSEQ			RECIP			UNPSEQ			PSEQ			RECIP		
fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv
mo	n/a	mo	mmoo	n/a	momo	moom	n/a	momo	om	n/a	oo	momo	n/a	momo	momo	n/a	momo
om		om	momo		moom	omom		moom	oo			moom		moom	moom		moom
		oo	moom		omom	oomo		omom				omom		omom	omom		omom
			omom			ooom		oomo				oomo		oomo	oomo		oomo
			oomo			oooo		ooom				ooom		ooom	ooom		ooom
			ooom					oooo				oooo		oooo	oooo		oooo
			oooo														

INEFFECTIVE GROUPS																	
Stable Environments									Dynamic Environments								
UNPSEQ			PSEQ			RECIP			UNPSEQ			PSEQ			RECIP		
fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv	fm	ostdv	pstdv
mm	n/a	mm	mmmm	n/a	mmmm	mmmm	n/a	mmmm	mm	n/a	mm	mmmm	n/a	mmmm	mmmm	n/a	mmmm
					mmmo	mmmo		mmmo			mo			mmmo			mmmo
					mmom			mmom						mmom			mmom
					mmoo			mmoo						mmoo			mmoo
					oomo												
					ooom												
					oooo												

Note: •UNPSEQ stands for unpartitionable sequential tasks, PSEQ stands for partitionable sequential tasks, & RECIP stands for reciprocal tasks.
•fm stands for financial measure, ostdv denoted for standard deviation of order delivery time, & pstdv standard deviation of manufacturing cycle time.
•First letter (i.e. 2, S, or R) from the names representing various extended enterprise models is omitted in the table to fit the table in one page.

. Table 5.28 Summary of effective and ineffective frameworks of the Final Experiment: the Pessimistic Model

CHAPTER SIX

Conclusions and Discussion

6.1 Introduction

This chapter summarizes the results of this research. Section 6.2 summarizes and concludes the research findings, as well as proposes practical and research implications of the research findings. Finally, limitations of this research and future research directions are discussed in Section 6.3.

6.2 Summary of the Research Findings

The objective of this research was two-fold: (1) to investigate the impact of the interactions of mechanistic and/or organic management control systems within an extended enterprise on organizational performance in both stable and dynamic environments, and (2) to demonstrate viability of both mechanistic and organic management control systems for inter-organizational control within an extended enterprise in both stable and dynamic environments. To achieve this objective, we adopted the contingent approach regarding management of organizations. With this contingent approach, we have employed system dynamics (SD) simulation models as the instrument of this research. Experimenting with SD simulation models helped us understand the interrelationships between multiple dependent (or contingent) variables (i.e. external environmental condition, interactions of mechanistic and/or organic management control systems, and structures of extended enterprises) and independent variables (i.e. organizational performance) in compressed time and space. Organizational performance was measured using three performance measures: (1) the sum over all periods, of inventory holding costs and stockout costs in each period (i.e. *FM*), (2) standard deviation of order delivery time over all periods (i.e. *OSTDV*), and (3) standard deviation of manufacturing cycle time over all periods (i.e. *PSTDV*) to measure the smoothness of production.

Across all three experiments, the *OSTDV* did not show statistical differences in performance among different management control systems framework, while the *FM* and *PSTDV* resulted in statistical differences. Interestingly, the *FM* and *PSTDV* often resulted in conflicting outcomes since high variability of production flow to match fluctuating customer demands resulted in low inventory holding costs, while low variability of production flow resulted in high inventory holding costs for inefficiently keeping large number of inventory.

Overall for all three sets of experiments, the results of hypotheses tests I through IV, supported the fundamental premises of this research that not only each contingent factor, but also the interaction among all three contingent factors effect organizational performance of an extended enterprise. Furthermore, the results of *post hoc* multiple comparisons using Scheffé tests partially supported the propositions suggested in Chapter 2. Table 6.1 summarizes the propositions and the result.

Although the statistical analyses results did not conclusively support every proposition, they demonstrated the anticipated phenomena identified by propositions such as overreaction and "system nervousness" of the management control systems frameworks with all organic management control systems (identified in *Proposition S1* and *D3*), superior organizational performance of the heterogeneous management control systems frameworks (*Proposition D2*), and the ordering effect of the heterogeneous management control systems in an extended enterprise (*Proposition D2a*). One possible explanation of these discrepancies between the propositions and the results is that there are more unidentified endogenous contingent factors within the closed-boundary of the system which may affect the behavior of the system, thus the propositions based on the limited contingent factor settings could not properly predict the behavior of the system. For example, the reaction rate (*1/k*) which was identified as "one of the more critical parameters in determining the system's dynamic performance" (Forrester, 1961), definitely needs to be put under closer scrutiny and should be included as an important contingent factor to be investigated for future replication of this research.

Propositions	Result
***Proposition S.1**: In stable environments, all four types of interactions of management control systems help extended enterprises maintain patterns in organizational activities in order to coordinate their cooperative efforts and keep them under control over time.*	Statistically, this proposition is rejected since statistical differences are found among different frameworks based on the four basic type of interactions of management control system with all three experiment. However with the second and final experiments, the *OSTDV* supports this proposition since all frameworks can help extended enterprises deliver products to the customer without any time delay, while the other two measures refute it.
***Proposition D.1**: In dynamic environments, interactions of the all mechanistic management control systems help the extended enterprise maintain patterns in organizational activities in order to coordinate their cooperative efforts and keep them under control over time. However, interactions of the all mechanistic management control systems may not promise a competitive advantage over interactions of either the combination of the mechanistic and organic management control systems, or all the organic management control systems because of the inefficiency of the mechanistic management control systems in dynamic environments.*	In most circumstances, this proposition is statistically supported with all three performance measures in three experiments. However, the all mechanistic management control systems frameworks become viable when the management cycle time become significantly faster than the manufacturing cycle time (e.g. the Optimistic model in the final experiment). thus the proposition is statistically rejected. Interestingly, a similar result is found in stable environments.
***Proposition D.2**: In dynamic environments, when an extended enterprise is established with manufacturing units with heterogeneous (mechanistic and organic) management control systems, interactions of heterogeneous management control systems help the extended enterprise maintain patterns in organizational activities in order to coordinate their cooperative efforts and keep them under control over time. Interactions of heterogeneous management control systems help motivate the extended enterprise to rapidly find an "excellent solutions" to keep its organizational activities in order.*	Statistically, this proportion cannot be examined since the Scheffé tests identify a group of effective frameworks in which there are no statistical differences among the frameworks in the effective group. However, the heterogeneous (mechanistic and organic) management control systems frameworks appeared to result in better organizational performance in the first experiment.
***Proposition D.2.a**: In dynamic environments, interactions of heterogeneous (mechanistic and organic) management control systems of individual manufacturing units in an extended enterprise may help the extended enterprise to rapidly find an "excellent solutions" over time. However, the organic-then-mechanistic management control systems helps the extended enterprise reach "excellent solutions" more effectively than the mechanistic-then-organic management control systems.*	Statistically, this proportion cannot be supported since the Scheffé tests identify a group of effective frameworks in which there are no statistical differences among the frameworks in the effective group. However, the optimistic-then-mechanistic management control systems frameworks appeared to result in better organizational performance than the mechanistic-then-organic ones in most circumstances.
***Proposition D.3**: In dynamic environments, when an extended enterprise is established with all organically managed manufacturing units, interactions of the all organic management control systems may not help the extended enterprise maintain patterns in organizational activities.*	This proposition is supported in the first experiment, the Optimistic model of the final experiment with financial measure. However even in stable environments, the all organic management control systems frameworks are identified as the least effective in the first experiment, the Optimistic model of the final experiment with financial measure.

Table 6.1 Propositions and experimental support obtained

However, the overall results indicated that the management control systems frameworks with heterogeneous management control systems resulted in satisfactory organizational performance across all three experiments. The heterogeneous management control systems frameworks always resulted in either the best or average organizational performance, but never the worst organizational performance. While the management control systems frameworks with either all mechanistic or organic management control systems resulted in either the best or the worst organizational performance contingent on the circumstances faced by the organization.

In most circumstances, the management control systems frameworks with all organic management control systems are effective due to a management practice we refer to as "managing in real time" which allows employees and managers to make decisions based on current transactions rather than after-the-fact summaries of transactions. In other words, by local empowerment, "managing in real time" reduces time delays in information flows between an entity which makes a decision and another entity which executes the decision. However, the management control systems frameworks with all organic management control systems become ineffective due to overreaction when the reaction rate of the management control system is too reactive (e.g. first experiment). As well this framework can cause "system nervousness" to an extended enterprise when the management cycle time becomes significantly faster than the manufacturing cycle time (e.g. the Optimistic model in the final experiment). Although this research did not investigate an exact ratio of manufacturing and management cycle times where the system becomes nervous, the future replication of this research should investigate this matter further.

On the other hand, in most circumstances, the management control systems frameworks with all mechanistic management control systems are ineffective due to a traditional practice of the mechanistic management control system known as "managing by results" (Johnson, 1995). However, these management control systems frameworks are viable when the management cycle time become significantly faster than the manufacturing cycle time (e.g. the Optimistic model in the final experiment).

However, interactions of the organic and mechanistic management control systems in a management control systems framework prevented the extended enterprise from overreacting and/or becoming nervous, because the inefficiency of the mechanistic management control system acted as a dampening mechanism to prevent the extended enterprise from reacting to minor change in inputs.

Furthermore, as competitive environments become dynamic, the order of the heterogeneous mechanistic and organic management control systems in a management control systems framework result in different organizational performance. The overall results indicated that the management control systems frameworks with sequentially organic and mechanistic management control systems (e.g. 2OM, SOMOM, and ROMOM) resulted in better organizational performance than the ones with sequentially mechanistic and organic management control systems (e.g. 2MO, SMOMO, and RMOMO) as environments become dynamic. Difference in organizational performance is explained by understanding that the manufacturing unit closer to the source of variability (i.e. the customer) acts as a buffer and dampens variability and passes down less dynamic or even stable environments to the partnering organization.

A buffer unit with the organic management control system in an extended enterprise can effectively and quickly lessen the degree of variability coming from dynamic environments. Since the mechanistic management control system works effectively in stable environments, interactions of the organic buffer and the mechanistic partner helps the extended enterprise result in satisfactory organizational performance while avoiding overreaction or "system nervousness." Whereas a mechanistically managed buffer cannot lessen the degree of variability coming from dynamic environments as effectively and fast as the organic one, but the mechanistic buffer does pass down less dynamic environments to the organically managed manufacturing unit. Since the organic management control system operates effectively in dynamic environments, interactions of the mechanistic buffer and the organic partner helps the extended enterprise result in satisfactory organizational performance.

In fact, the use of management control systems frameworks with heterogeneous organic and mechanistic management control systems can be seen as an application of "Ashby's Law of Requisite Variety" (Ashby, 1956, Ch.11), which basically states that only variety in responses can effectively deal with the variety due to disturbances. Each of the mechanistic and the organic management control system alone has its drawback, such as "system nervousness" of the organic management control systems and ineffectiveness of the mechanistic ones in dynamic environment. However, the use of mechanistic and organic management control systems together complements (or dampens) each other's shortcoming, while helping an extended enterprise to effectively manage and control the complexity arising from the increased variability and disturbances.

Practical Implication

The recent literature on intra-organizational control continues to recommend individual manufacturing organizations adopt new management paradigms, such as decentralized control and the organic model of control as business environments become dynamic. However, the adoption of such recommendation may result in poor organizational performance in certain situations for organizations participating in cooperative and decentralized manufacturing such as the extended enterprise. As the results of the Optimistic model of the final experiment indicate, when the management cycle time becomes significantly faster than the manufacturing cycle time, the management control systems frameworks with all organic management control system results in financially poor organizational performance than the ones with all mechanistic management control systems due to "system nervousness." As well, the results of the first experiment showed that the management control systems frameworks with all organic management control system again results in financially poor organizational performance than the ones with all mechanistic management control systems due to high reaction rate. Furthermore, the results of the Middle model of the final experiment showed that the management control systems frameworks with mixture of the organic and mechanistic management control systems result in superior organizational performance of an extended enterprise than the ones with all organic management control systems with partitionable sequential or reciprocal tasks. As the experiment results demonstrate, not every manufacturing organization needs to change and adopt this new model of control. In extended enterprises, depending on how manufacturing organizations with heterogeneous and/or homogeneous management control systems are structured, results will vary.

Furthermore, a sound structure of organization is identified to help an organization succeed (Meyer, 1995) and further a sound framework of management control systems may help an organization succeed as well. However, as the results of the first experiment suggest: a perceived "sound" framework of management control systems (i.e. the all organic management control systems) with a bad management policy (i.e. reaction rate) does not help an extended enterprise to perform better.

Research Implication

As business and manufacturing environments become dynamic and unpredictable, the Next-Generation Manufacturing (NGM) Project (1997) identified extended enterprise collaboration as "a pathway along which individual companies, in association with other companies, academia, and government, can improve the odds of making a successful transition to the NGM environment through collaboration with other companies." As one of action recommendation in order to make this new type of collaborative manufacturing works, the NGM identified the need for a "Collaborative Extended Enterprise Laboratory to pilot and validate tools, approaches, and practices supporting extended enterprise concepts." A system dynamics (SD) simulation model -- also known as "management laboratory" (Forrester, 1961)-- was employed as the research instrument in our research and it was demonstrated that the potential use of the SD model as a research instrument for future research on extended enterprises.

6.3 Limitations and Future Research

There are factors concerning the research that may have limited the findings and the generalization of this study and they should be mentioned.

A major limitation of this study is the performance measurements used to evaluate organizational performance. We have adopted traditional performance measures to measure effectiveness of a specific management control systems framework of extended enterprises. However, there is still a lack of understanding of how to measure and analyze the risks and/or rewards of the extended enterprise concept to evaluate the viability and financial benefits of a specific collaborative partnership (Montgomery and Levine, 1996; NGM, 1997).

Another limitation of this research is that we assumed individual manufacturing units can easily work together without problems based on the principal of self-organization, which is defined as "a process in which the components of a system in effect spontaneously communicate with each other and abruptly cooperate in coordinated and concerted common behaviour" (Stacey, 1991). However, more coordination and management issues must be managed and addressed within the extended enterprises. Differences in culture, business systems, and accounting practices, different approach/content/definition for same common words, the appropriate distribution of profits, coordination and finance of investments across firms, and assumption of responsibility for product liability are some of many issues remain unresolved regarding the management of such extended enterprises (Montgomery and Levine, 1996; NGM, 1997).

The environmental range settings for this research presents another limitation. For simplicity, we have used different degrees of customer demand fluctuation as the factor which differentiated between stable and dynamic environments. However, the future replication of this research should include environmental uncertainty such as technological unpredictability to differentiate stable and dynamic environments. Furthermore, we have eliminated potential disturbance or variability coming from supplier side by assuming suppliers can provide unlimited amount of raw materials at any time. However, the future replication of this research should examine disturbance and variability coming from both customer and supplier since this change may affect the behavior of the system dramatically.

Several forms of extended enterprises such as a value network, web, or chain, were identified by NGM (1997). This research examined only limited structures of extended enterprises based on the form of chain which involved limited number of individual manufacturing units. However, in order to examine different structures of extended enterprises which includes larger number of manufacturing units involvement, we must address what Brooks (1975) refers to "the mythical man-month" problem. According to Brooks' law (1975), "adding (more) manpower to a late software project makes it later" due to the added burden of communication and coordination effort. Analytically, it implies that for extended enterprises, the involvement of more and more companies does not necessarily lead to a stronger coverage of the problem due to the increased coordination requirement of the cooperative efforts. Thus, as the number of partners (N) working on partitionable complex tasks increases, the cooperative effort or coordination cost increases by $N \cdot (N-1)/2$ (Brooks, 1975), while the amount of work that an individual partner decreases by some amount (we will assume $N/2$). This tradeoff between coordination cost and the amount of work is illustrated in Figure 6.1. We have partially incorporated Brooks' law in this research up to the point where the coordination costs of total number of manufacturing in extended enterprise did not offset the benefits of the cooperative efforts (i.e. decrease in total effort). However, as the number of manufacturing units in extended enterprises increases, this tradeoff relationship between cost and benefit must be fully incorporated in the analyses of the future replication of this research.

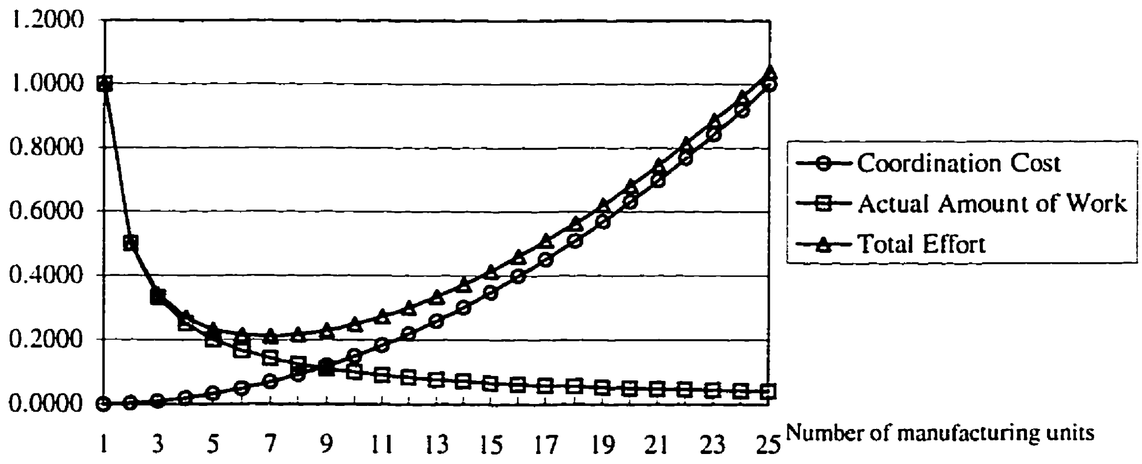


Figure 6.1 Illustration of tradeoff between coordination cost and individual units' amount of work

One last important limitation of the research identified is that the lack of understanding of relationship between the reaction rate ($1/k$) and the behavior of the extended enterprises. As the experiments evolved, we have identified the importance of the reaction rate ($1/k$) in determining the system's dynamic performance as suggested by Forrester (1961). We were able to select values (*l/k*) as Forrester suggested (1961) and study the effect of changing values on the behavior of the system. However, the future replication of this study should examine the effects of reaction rate (*l/k*) on the behavior of the system more closely prior to conducting experiments.

Final Remark

At the stroke of midnight Monday, July 1, 1997, Hong Kong and the People's Republic of China became a country with two (control) systems --capitalist Hong Kong and communist-led mainland China. Before this merge took place, there was high uncertainty about the future of Hong Kong and in fact, the future of Hong Kong is still unclear. Manufacturing organizations are facing similar problems as the competitive environments become dynamic and even chaotic, and they are in a way forced to work together with partners under a roof called "extended enterprise" in order to survive in highly competitive business environments. They are essentially establishing "one country, two systems" like China and Hong Kong. China and especially Hong Kong did not have much alternative as to how to structure this formula. However, manufacturing organizations may have options as to who to work with, how to structure their cooperative efforts, and more specifically how to structure their control systems for superior organizational performance. We believe this exploratory research provides an initial step for establishing a useful "management laboratory" where manufacturing organizations can pilot and validate tools, approaches, and practices before they actually establish extended enterprises, thus to improve the odds of making a successful transition to the extended enterprises.

Appendix 1

A Basic Manufacturing Organization Model Documentation and Equations with the Mechanistic Management Control System

ithink® Model Entity	*Unit*
Customer_Demands	Unit of measure for a product / Week (expressed in Graph (unit/week) with a mean demand)
Customer_Orders	Unit of measure for a product / Week
Customer_Order_Received	Unit of measure for a product / Week
Generate_CO_Report	Unit of measure for a product / Week
VP_Marketing	Unit of measure for a product / Week
Target_Inventory	Unit of measure for a product
VP_Manufacturing	Unit of measure for a product / Week
Production_Starts	Unit of measure for a product / Week
Production_Process	Unit of measure for a product / Week
Producing	Unit of measure for a product / Week
Inventory	Unit of measure for a product
Weekly_Shipping	Unit of measure for a product / Week
In_Transit_to_Customer	Unit of measure for a product / Week
Weekly_Sales_to_Consumer	Unit of measure for a product / Week
Order_Rate	Unit of measure for a product / Week
Order_Backlog	Unit of measure for a product
Shipment_Rate	Unit of measure for a product / Week
Weekly_Shipping_Report	Unit of measure for a product / Week
Inventory_Report	Unit of measure for a product
Order_Backlog_Report	Unit of measure for a product
Producing_Report	Unit of measure for a product / Week
President	a constant which sets inventory policy (the target inventory level) and production policy (how_much_to_correct_a_week)
how_much_to_correct_a_week	a time constant (= smoothing parameter)

Summary of unit of measures used

CUSTOMER:
DOCUMENT: The customer demands for product. For simplicity the customer demand represents the dynamics of the environments.
•Customer_Orders = Customer_Demands
DOCUMENT: The customer order rate is determined by the customer demand graph. For simplicity, the customer order rate will determine the dynamics of environment.

•Customer_Demands = GRAPH(time)
(1.00, 4000), (2.00, 4000), (3.00, 4000), (4.00, 4000), (5.00, 4000), (6.00, 4000), (7.00, 4000), (8.00, 4000), (9.00, 4000), (10.0, 4000), (11.0, 4000), (12.0, 4000), (13.0, 4000), (14.0, 4000), (15.0, 4000), (16.0, 4000), (17.0, 4000), (18.0, 4000), (19.0, 4000), (20.0, 4000), (21.0, 4000), (22.0, 4000), (23.0, 4000), (24.0, 4000), (25.0, 4000), (26.0, 4000), (27.0, 4000)
DOCUMENT: Customer Demands fluctuate with a mean demand(X). The magnitude of fluctuation differentiates between stable and dynamic environments.

MANAGEMENT:
DOCUMENT: The management represents the management function of the basic manufacturing framework. The management receives the customer order information from the Marketing and the backorder level, inventory level, throughput in manufacturing process, and weekly shipping reports from the Production Process. With information gathered from the Marketing and Production, the Management decides what to produce and how much o produce. Once the decision is made, the production decision is sent down to the Production Process (i.e. shop floor).

•how_much_to_correct_a_week = President/2
DOCUMENT: It represents the production policy and the production policy tries to compensate for the amount of the products shipped during the last period and also to make necessary adjustment on inventory- and pipeline-deficit situations. The inventory policy states that Target Inventory is set to be a multiple of customer Order Rate. And summation between Target Inventory and (actual) Inventory levels, and Order Backlog level and indicates how many more units of a product, such as Alpha should be in the Inventory to satisfy the customer demand. Whereas the difference between Customer Order Received and Producing shows how many units of Alpha should be currently in production process (i.e. production pipeline) to satisfy the customer demand. However it is assumed that management would not respond immediately to the full extent of any adjustment required due to these two deficit terms. Thus this adjustment term, which is the summation of the two deficit terms, is multiplied by a rate - 1/how much to correct a week, which is a time constant representing the rate at which management, on average act on the adjustment term. In fact, this 1/how much to correct a week term is similar to a smoothing parameter, alpha of the exponential smoothing forecasting method for customer demand. As lager the alpha values emphasize recent demands and result in forecasts more responsive to changes in the underlying average, while smaller alpha values treat past demand more uniformly and result in more stable forecasts, same argument is true for 1/how much to correct a week term.

•President = 3

DOCUMENT: The President sets inventory policy (i.e. the target inventory level) and production policy (i.e. how_much_to_correct_a_week). (initial constant value 3)

•Target_Inventory = VP_Marketing*President
DOCUMENT: Target Inventory rate is decided by the President. Then this target inventory information is delivered to VP manufacturing.

•VP_Manufacturing = (DELAY(MAX(0, Weekly_Shipping_Report+(1/how_much_to_correct_a_week) * ((Target_Inventory-Inventory_Report+Order_Backlog_Report)+(VP_Marketing- Producing_Report))),0.25))
DOCUMENT: VP Manufacturing with the President and VP Marketing decides production ordering rate with various reports received from the Manufacturing (i.e. shop floor) and it takes a substantial amount of time (initial value: 0.25 week) to decide and to deliver the order down to the shop floor. It is a phase three of the order cycle when "getting the order into the system" begins (routing the orders to the shop floor). The decision rule is set as follows: First, the production ordering rate decision depends on the full amount of outgoing rate of the inventory (i.e. Weekly Shipping Report). Second, Target Inventory and Inventory Report (current inventory level) give the difference between desired and actual inventory. If the level of desired inventory (Target Inventory) is above or below actual inventory, a correcting component will be introduced into the production ordering rate. Third, VP Marketing (i.e. Customer Order Report) and Producing Report give the pipeline term meaning desired outgoing number of units (VP Marketing) that customer demands and actual outgoing number of units (Producing Report). The difference between these two terms will be added to the correcting component. Lastly, the amount of backlog order is introduced into the correcting component as well. A proportion of the sum of these last three correcting components are added to the full amount of outgoing rate inventory.

•VP_Marketing = Generate_CO_Report
DOCUMENT: The VP Marketing receives the CO Report (order information) from the Marketing then communicates this information to the VP Manufacturing.

MARKETING:
DOCUMENT: The Marketing Process identifies the customer demand for existing and new products and communicates this information to the Management.

•Weekly_Sales_to_Consumer = CONVEYOR OUTFLOW
DOCUMENT: It takes some time (initial value 0.25 week) to ship the products to the Marketing. Once the product is available in the Marketing, it takes no substantial amount of time to deliver the product to the customer. It is the fifth phase of the order cycle where the products are on the way to the customer.

•OUTFLOW FROM: In_Transit_to_Customer (IN SECTOR: Production)

•Customer_Order_Received = Customer_Orders

DOCUMENT: The Marketing Process first receives customer orders and there is no delay getting this information from the customer. This is the first and second phase of the order cycle where the system translates the recognized need of customer into an approved order for a specific product or a new product and delivers the order to the relevant group in the organization. It is assumed that each manufacturing unit has access to the technology and therefore technology is not a limiting factor. Similarly, the product the manufacturing unit produces is completely designed and standard.

•Generate_CO_Report = DELAY(Customer_Order_Received,0.25)
DOCUMENT: Once the Marketing has the order in-house, this Generate Customer Order (CO) Report process delivers the customer order to the VP Marketing. It is the third phase of the order cycle and it actually get the order into the system. It takes a substantial amount of time (initial value 0.25 week) to process and deliver the information.
Note: Throughout the model, delay function is used to simulate the dynamic environment of the manufacturing organization. The length of each delay is estimated by surveying a few literature. The length of delay can be easily changed if one desires.

PRODUCTION:
DOCUMENT: The Production Process receives the production orders from the Management and executes the orders. As well the Production reports various information such as Backorder level status, Inventory level etc. to the Management.

•Inventory(t) = Inventory(t - dt) + (Producing - Weekly_Shipping) * dt
INIT Inventory = 12000
DOCUMENT: Initial inventory level is 12000 units of Alpha

•Producing = CONVEYOR OUTFLOW
DOCUMENT: It takes a substantial amount of time (initial value: 0.25 week) to produce any products. It is a part of phase four of the order cycle where actual assembling, picking, and packing of goods are processed.

•Weekly_Shipping = (if (Order_Backlog+Order_Rate <=Inventory) then
Order_Backlog+Order_Rate
else Inventory)
DOCUMENT: Weekly Shipping of product is processed, based on FIFO (First In First Out) policy. The decision rule is as follows: If the Manufacturing has enough inventory to satisfy the backlogged order (Order Backlog) and the current period's customer order rate (Order Rate) then the Manufacturing ships the amount equal to the sum of the backlog order and the customer demand. But, if the inventory level is lower than the sum of the two terms and greater than 0, then the manufacturing ships out the number of units in the inventory to at least fulfill the part of backlogged order and/or current period's customer demand.

•In_Transit_to_Customer(t) =In_Transit_to_Customer(t - dt) +
(Weekly_Shipping-Weekly_Sales_to_Consumer)* dt

INIT In_Transit_to_Customer = 1000
TRANSIT TIME = 0.25
INFLOW LIMIT = INF

CAPACITY = INF
DOCUMENT: Initial 1000 units of Alpha is shipped to the Marketing.

•Weekly_Shipping = (if (Order_Backlog+Order_Rate <=Inventory) then Order_Backlog+Order_Rate
else Inventory)
DOCUMENT: Weekly Shipping of product is processed, based on FIFO (First In First Out) policy. The decision rule is as follows: If the Manufacturing has enough inventory to satisfy the backlogged order (Order Backlog) and the current period's customer order rate (Order Rate) then the Manufacturing ships the amount equal to the sum of the backlog order and the customer demand. But, if the inventory level is lower than the sum of the two terms and greater than 0, then the manufacturing ships out the number of units in the inventory to at least fulfill the part of backlogged order and/or current period's customer demand.

•Weekly_Sales_to_Consumer (IN SECTOR: Marketing)

•Order_Backlog(t) = Order_Backlog(t - dt) + (Order_Rate - Shipment_Rate) * dt

INIT Order_Backlog = 0
DOCUMENT: Order Backlog level is initially 0 for a product.

•Order_Rate = VP_Marketing
DOCUMENT: This order rate information from the Management is necessary to keep any Order Backlog level. It increases the level of Order Backlog when a new customer demand comes in if the demand cannot be satisfied with the inventory, but if the amount of this customer demand (order rate) is delivered, then the amount delivered is decreased through weekly shipping and filled order flows from the Order Backlog level.

•Shipment_Rate = Weekly_Shipping
DOCUMENT: The amount of filled order is decreased from the Order Backlog level as products are shipped to the customer.

•Production_Process(t) = Production_Process(t - dt) + (Production_Starts - Producing) * dt
INIT Production_Process = 1000
TRANSIT TIME = 0.25
INFLOW LIMIT = INF
CAPACITY = INF
DOCUMENT: Initially 1000 units of Alpha is produced every 0.25 week (or 4000 units per week).

•Production_Starts = DELAY(VP_Manufacturing,0.25)

DOCUMENT: It initiates production according to the VP Manufacturing's order. It takes a substantial amount of time (initial value: 0.25 week) to setup the production line for a new order. It is a part of fourth phase of the order cycle, where actual production of goods is initiated.

•Producing = CONVEYOR OUTFLOW
DOCUMENT: It takes a substantial amount of time (initial value: 0.25 week) to produce any products. It is a part of phase four of the order cycle where actual assembling, picking, and packing of goods are processed.

•Inventory_Report = DELAY(Inventory, 0.5)
DOCUMENT: Inventory Level Report is reported to the VP Manufacturing. It takes 0.5 week to prepare and deliver the report to the VP Manufacturing.

•Order_Backlog_Report = DELAY(Order_Backlog,0.5, 0)
DOCUMENT: It takes 0.5 week to prepare and deliver Order Backorder Report to the VP Manufacturing.

•Producing_Report = DELAY(Producing,0.5)
DOCUMENT: It takes 0.5 week to prepare and deliver Producing Report (how many units is being produced) to the VP Manufacturing.

•Weekly_Shipping_Report = DELAY(Weekly_Shipping, 0.5)
DOCUMENT: Weekly Shipping Report is reported to the VP Manufacturing. It takes 0.5 week to prepare and to deliver the report.

Appendix 2.

A Basic Manufacturing Organization Model Documentation and Equations with the Organic Management Control System

ithink® Model Entity	*Unit*
Customer_ Demands	Unit of measure for a product / Week (expressed in Graph with a mean demand)
Customer_ Orders	Unit of measure for a product / Week
Customer_Order_Received	Unit of measure for a product / Week
Production_Decision	Unit of measure for a product / Week
Production_Starts	Unit of measure for a product / Week
Production_Process(t)	Unit of measure for a product / Week
Producing	Unit of measure for a product / Week
Inventory	Unit of measure for product
Weekly_Shipping	Unit of measure for a product / Week
In_Transit_to_Consumer(t)	Unit of measure for a product / Week
Weekly_Sales_to_Consumer	Unit of measure for a product / Week
Order_Rate	Unit of measure for a product / Week
Order_Backlog(t)	Unit of measure for a product
Shipment_Rate	Unit of measure for a product / Week
how_much_to_correct_a_week	a time constant (= smoothing parameter)

Summary of unit of measures used

CUSTOMER:
DOCUMENT: The customer demands for product. For simplicity the customer demand represents the dynamics of the environments.

•Customer_Orders = Customer_Demands_for_Alpha
DOCUMENT: The customer order rate is determined by the customer demand graph. For simplicity, the customer order rate determines the dynamics of the environments .

•Customer_Demands_for_Alpha = GRAPH(time)
(1.00, 4000), (2.00, 4000), (3.00, 4000), (4.00, 4000), (5.00, 4000), (6.00, 4000), (7.00, 4000), (8.00, 4000), (9.00, 4000), (10.0, 4000), (11.0, 4000), (12.0, 4000), (13.0, 4000), (14.0, 4000), (15.0, 4000), (16.0, 4000), (17.0, 4000), (18.0, 4000), (19.0, 4000), (20.0, 4000), (21.0, 4000), (22.0, 4000), (23.0, 4000), (24.0, 4000), (25.0, 4000), (26.0, 4000), (27.0, 4000)
DOCUMENT: Customer Demands fluctuate with a mean demand (X). The magnitude of fluctuation differentiates between stable and dynamic environments.

MANUFACTURING ORGANIZATION:
DOCUMENT: It is a manufacturing system with the organic management control system.

•Inventory(t) = Inventory(t - dt) + (Producing - Weekly_Shipping) * dt
INIT Inventory = 12000
DOCUMENT: Initially there are 12000 units of product Alpha in the inventory.

•Producing = CONVEYOR OUTFLOW
DOCUMENT: It takes 0.25 weeks to produce product Alpha.

•Weekly_Shipping = (if (Order_Backlog+Order_Rate <=Inventory) then
Order_Backlog+Order_Rate
else Inventory)
DOCUMENT: Weekly Shipping of product is processed, based on FIFO (First In First Out) policy. The decision rule is as follows: If we have enough inventory to satisfy the backlog order and the current period's customer order rate then we ship the amount equal to the sum of the backlog order and the customer demand. Otherwise, we ship out the number of units in the inventory.

•In_Transit_to_Consumer(t) = In_Transit_to_Consumer(t - dt) + (Weekly_Shipping - Weekly_Sales_to_Consumer) * dt
INIT In_Transit_to_Consumer = 1000
TRANSIT TIME = 0.25
INFLOW LIMIT = INF
CAPACITY = INF
DOCUMENT: Initially 1000 units of Alpha is shipped to the customer.

•Weekly_Shipping = (if (Order_Backlog+Order_Rate <=Inventory) then
Order_Backlog+Order_Rate
else Inventory)
DOCUMENT: Weekly Shipping of product is processed, based on FIFO (First In First Out) policy. The decision rule is as follows: If we have enough inventory to satisfy the backlog order and the current period's customer order rate then we ship the amount equal to the sum of the backlog order and the customer demand. Otherwise, we ship out the number of units in the inventory.

•Weekly_Sales_to_Consumer = CONVEYOR OUTFLOW
DOCUMENT: Once the products are ready, it takes 0.25 week to ship them out to the customer.

•Order_Backlog(t) = Order_Backlog(t - dt) + (Order_Rate - Shipment_Rate) * dt
INIT Order_Backlog = 0
DOCUMENT: Order Backlog level is initially 0 for a product.

•Order_Rate = Customer_Order_Received
DOCUMENT: It increases the level of Order Backlog when a new customer demand come in if the demand cannot be satisfied with the Inventory, but if the amount of this customer demand (order rate) is delivered, then the amount delivered is decreased through weekly shipping and filled order flows from the Order Backlog level.

•Shipment_Rate = Weekly_Shipping
DOCUMENT: The amount of filled order is decreased from the Order Backlog Level.

•Production_Process(t) = Production_Process(t - dt) + (Production_Starts - Producing) * dt
INIT Production_Process = 1000
TRANSIT TIME = 0.25
INFLOW LIMIT = INF
CAPACITY = INF
DOCUMENT: Manufacturing function processes 1000 units of, for example Alpha a week.

•Production_Starts = DELAY(Production_Decision, 0.25)
DOCUMENT: It initiates production according to the Production Decision. It takes 0.25 week to setup the production line for a new product. It is a part of the order cycle where actual assembling, picking, and packing of goods are processed.

•Producing = CONVEYOR OUTFLOW
DOCUMENT: It takes 0.25 weeks to produce product Alpha.

•Customer_Order_Received = Customer_Orders
DOCUMENT: The company receives the customer orders and there is no delay getting this information from the customer. This is the first and second phase of the order cycle where the

system translates the recognized need of the customer into an approved order for a specific product or a new product.

•how_much_to_correct_a_week = 1.5 + (Customer_Order_Received + Inventory)*0
DOCUMENT: A time constant representing the rate at which the retailers, on the average, act on inventory- and pipeline-deficit situations. It is not to be assumed that retailers would respond immediately to the full extent of any theoretical difference between desired and actual inventory. Furthermore, the time lags in observing such differences may sometimes be substantial. The constant allows adjustment of this response time. For example, a value of fours weeks for the constant would give a production rate that corrects any remaining deficit (the terms in brackets of the Production Decision which is multiplied by the term 1/how much to correct a week) at the rate of one quarter of the deficit per week. As for another example, if the constant is one week then the system would correct full amount of weekly deficit. (Note: Customer_Order_Received and Inventory information will be used to make this how_much_to_correct parameter varies according to Customer_Order_Received and Inventory)

•Production_Decision = (MAX(0, (Weekly_Shipping)+(1/how_much_to_correct_a_week)*(((Customer_Order_Received*3)-Inventory+Order_Backlog)+(Customer_Order_Received-Producing))))
DOCUMENT: Production_Decision attempts to compensate for the amount of products shipped during the last period and also to make a necessary adjustment on inventory- and pipeline-deficit situations. The inventory policy states that Target_Inventory is initially set to be a multiple of customer Order_Rate. And summation of the difference between Target_Inventory and (actual) Inventory levels, and Order_Backlog level indicates how many more units of a product Alpha should be in the Inventory to satisfy the customer demand. Whereas, the difference between Customer_Order_Received and Producing shows how many units of a product Alpha should be currently in production process (i.e. in production pipeline) to satisfy the customer demand. However, it is assumed that management would not respond immediately to the full extent of any adjustment required due to these two deficit terms. Thus this adjustment term, which is the summation of the two deficit terms, is multiplied by a rate - 1/how_much_to_correct_a_week, which is a time constant representing the rate at which management, on average act on the adjustment term. In fact, this 1/how_much_to_correct_a_week term is similar to a smoothing parameter, alpha (α) of the exponential smoothing forecasting method for customer demand. "Lager α values emphasize recent demands and result in forecasts more responsive to changes in the underlying average, while smaller α values treat past demand more uniformly and result in more stable forecasts" (Krajewski and Ritzman, 1992) and the same argument is true for 1/how_much_to_correct_a_week term. Since Production_Rate should be always greater than or equal to zero, the MAX function is used to prevent Production_Rate from taking on negative values. And this Production_Rate constitutes the Products Produced part of the classic inventory equation which in turn increases the level of Inventory and Order_Backlog.

Appendix 3.

Tests Results for Building Confidence in Basic Manufacturing Organization Model with the Mechanistic Management Control System

Tests For Building Confidence for Basic Manufacturing Model with Mechanistic Model of Control	
Test of model structure	
Structure Verification	The underlying production line structure (i.e. the physical goods producer part) of the model is based on Forrester's production-distribution SD model (1961). Then the mechanistic management control system (i.e. information processor) is added on the production line using a description given by Burns and Stalker (1961) and Hofstede (1978). We purposely made the structure simple, so that it is to easy to understand the model (and various causal relationships within the model).
Parameter (constant) Verification	There are a few artificial delays embedded in the model in order to simulate the dynamics of the system (e.g. the order cycle). The initial parametr values we used for the order cycle in the simulation model is based on a survey done by La Londe and Zinszer (1976). however, these values can easily be changed if needed. The default value for 'how much to correct a week' parameter is set to 1.5. It is because, after a few sensitivity tests with the value, the value 1.5 was determined to give relatively good performance result for the model. Thus, 1.5 was choosed to be the default value for this parameter, but again this value can easily be changed.
Extreme Conditions	We have tested the model with the following scenario: 1) No orders for Alpha: there was no production activity. 2) Extremely large value for initial Alpha inventory: again there was no production activity.
Boundary Adequacy (Structure)	The real manufacturing system is much more complicated than this rather simplified model of manufacturing organization. The actual manufacturing system would have many more variables and parameters that may influence the decision making processes. However, we have included the necessary structural relationships that we can demonstrate how well a manufacturing organization satisfies the customer's demands with regard to different types of management control systems which managers use to maintain or alter patterns in organizational activities. Organizational structure, the delay in decisions and actions, and the policies governing purchases, productions, and inventories together constitute a manufacturing management control system.
Dimensional Consistency	We have implemented consistent unit measures for Alpha. In addition, ithink software consistently applies an equal length of delta time "DT" which is "the interval of time between calculations" (High Performance Systems, Inc. 1996). 0.25 week

	is used for the models (meaning a round of calculations will be performed every 1/4 of a week or four rounds of calculations would be performed per week). 0.25 week was determined after the 1/2 test recommended by High Performance Systems, Inc (1996).
	Test of model behaviour
Behavior Reproduction	The model has been tested using the typical scenario used in the Beer Distribution Game - the customer demand for Alpha starts with 4000 units then in the middle of a simulated year, the demand suddenly jumps up to 8000 units. Manufacturing organization with mechanistic model of control exhibited the similar oscillation pattern in inventory level when the demand for Alpha was perturbed, then slowly stabilized the inventory level as we expected (it exhibited one of the classical mode of behavior of a negative feedback loop - delayed loop).
Behavior Prediction	N/A
Behaviour Anomaly	We did not experience any anomalous behaviors.
Family Member	With modification of a few parameters and length of delays, these models can reproduce the behaviour of different manufacturing systems.
Surprise Behaviour	We did not find any surprise behaviors.
Extreme Policy	The system experiences the system nervousness if we change our inventory system from periodic to perpetual review systems. (if we change the constant :how much to correct a week to 1, the system starts to exhibit the system nervousness)
Boundary Adequacy (Behaviour)	please see the Boundary Adequacy Structure Test for model structure
Behaviour Sensitivity	With all the assumptions placed within the model, we have not been able to find alternative parameter values that would cause the model to fail behavior tests previously passed.
Statistical Character	N/A
	Tests of policy implications
System Improvement	N/A
Changed-Behaviour Prediction	We were able to stabilize inventory level faster by shortening the information processing delay parameter as we predicted. The manufacturing organization model with the mechanistic management control system exhibits delayed loop.
Boundary Adequacy (Policy)	please see the Boundary Adequacy Structure Test for model structure
Policy Sensitivity	N/A

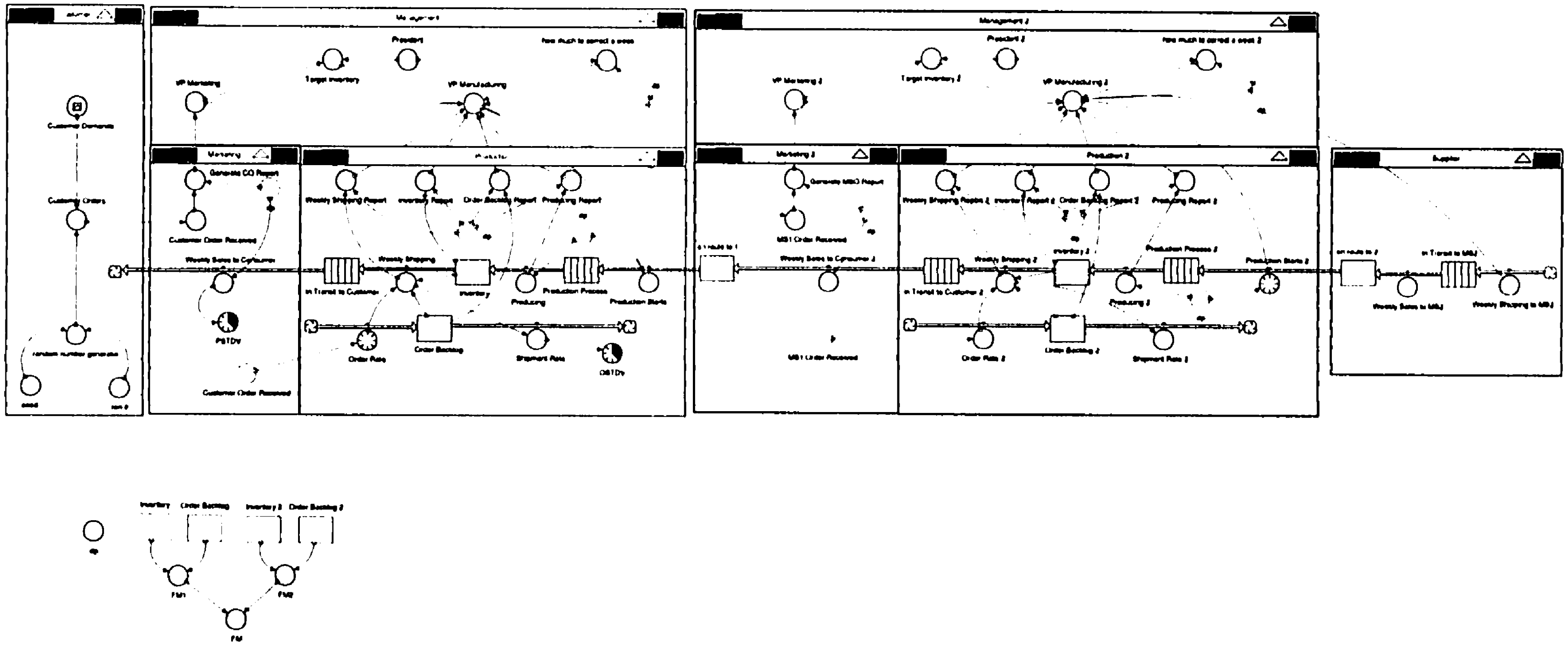
Appendix 4.

Tests Results for Building Confidence in Basic Manufacturing Organization Model with the Organic Management Control System

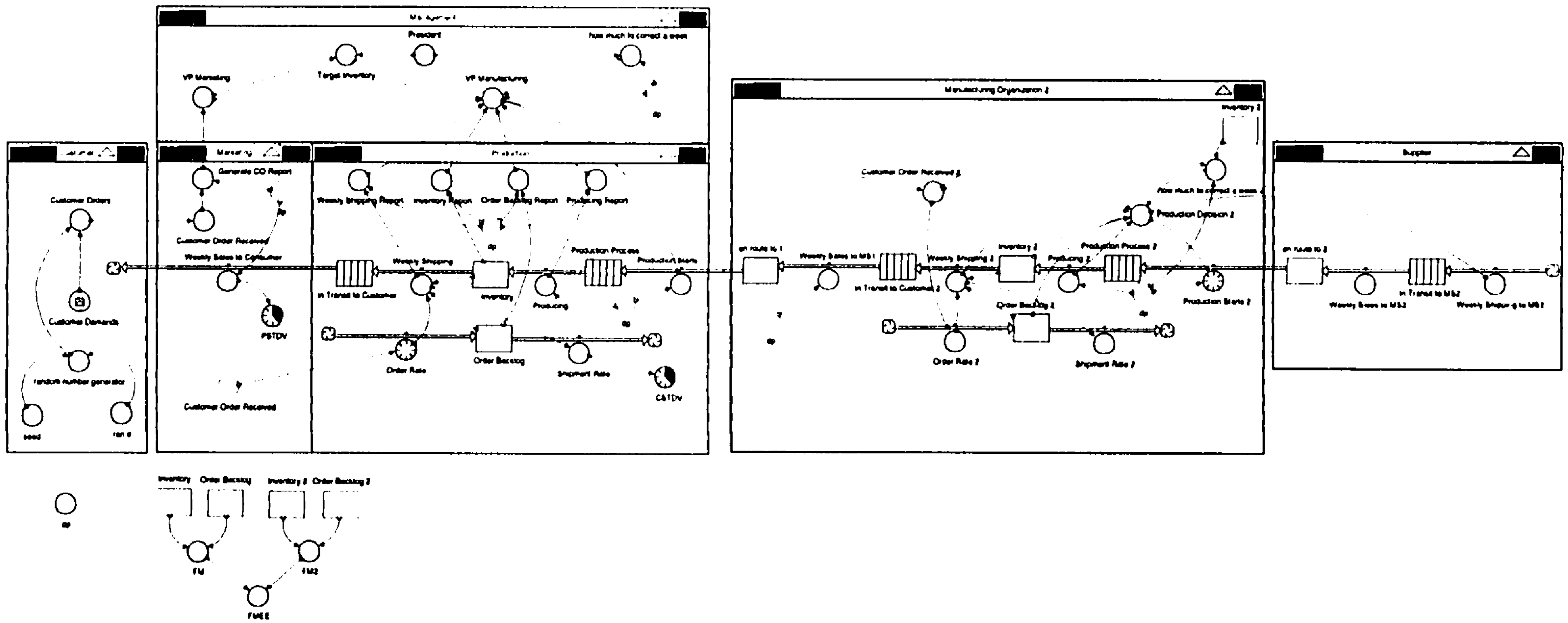
Tests For Building Confidence for Basic Manufacturing Model with Organic Model of Control	
Test of model structure	
Structure Verification	The underlying production line structure (i.e. the physical goods producer part) of the model is based on Forrester's production-distribution SD model (1961). Then the mechanistic management control system (i.e. information processor) is added on the production line using a description given by Burns and Stalker (1961) and Hofstede (1978). We purposely made the structure simple, so that it is to easy to understand the model (and various causal relationships within the model).
Parameter (constant) Verification	There are a few artificial delays embedded in the model in order to simulate the dynamics of the system (e.g. the order cycle). The initial parametr values we used for the order cycle in the simulation model is based on a survey done by La Londe and Zinszer (1976). however, these values can easily be changed if needed. The default value for 'how much to correct a week' parameter is set to 1.5. It is because, after a few sensitivity tests with the value, the value 1.5 was determined to give relatively good performance result for the model. Thus, 1.5 was choosed to be the default value for this parameter, but again this value can easily be changed.
Extreme Conditions	We have tested the model with the following scenario: 1) No orders for Alpha: there was no production activity. 2) Extremely large value for initial Alpha inventory: again there was no production activity.
Boundary Adequacy (Structure)	The real manufacturing system is much more complicated than this rather simplified model of manufacturing organization. The actual manufacturing system would have many more variables and parameters that may influence the decision making processes. However, we have included the necessary structural relationships that we can demonstrate how well a manufacturing organization satisfies the customer's demands with regard to different types of management control systems which managers use to maintain or alter patterns in organizational activities. Organizational structure, the delay in decisions and actions, and the policies governing purchases, productions, and inventories together constitute a manufacturing management control system.
Dimensional Consistency	We have implemented consistent unit measures for Alpha. In addition, ithink software consistently applies an equal length of delta time "DT" which is "the interval of time between calculations" (High Performance Systems, Inc. 1996). 0.25 week is used for the models (meaning a round of calculations will be performed every 1/4 of a week or four rounds of calculations would be performed per

	week). 0.25 week was determined after the 1/2 test recommended by High Performance Systems, Inc (1996).
Test of model behaviour	
Behavior Reproduction	The model has been tested using the typical scenario used in the Beer Distribution Game - the customer demand for Alpha starts with 4000 units then in the middle of a simulated year, the demand suddenly jumps up to 8000 units. The manufacturing organization model with the organic management control exhibited undelayed loop with the same test as we expected since there was no information delay within the system.
Behavior Prediction	N/A
Behaviour Anomaly	We did not experience any anomalous behaviors.
Family Member	With modification of a few parameters and length of delays, these models can reproduce the behaviour of different manufacturing systems.
Surprise Behaviour	We did not find any surprise behaviors.
Extreme Policy	The system experiences the system nervousness if we change our inventory system from periodic to perpetual review systems. (if we change the constant :how much to correct a week to 1, the system starts to exhibit the system nervousness)
Boundary Adequacy (Behaviour)	please see the Boundary Adequacy Structure Test for model structure
Behaviour Sensitivity	With all the assumptions placed within the model, we have not been able to find alternative parameter values that would cause the model to fail behavior tests previously passed.
Statistical Character	N/A
Tests of policy implications	
System Improvement	N/A
Changed-Behaviour Prediction	We were able to stabilize inventory level faster by shortening the information processing delay parameter as we predicted. The manufacturing organization model with the organic control system exhibits one of the classical mode of behavior of a negative feedback loop - undelayed loop.
Boundary Adequacy (Policy)	please see the Boundary Adequacy Structure Test for model structure
Policy Sensitivity	N/A

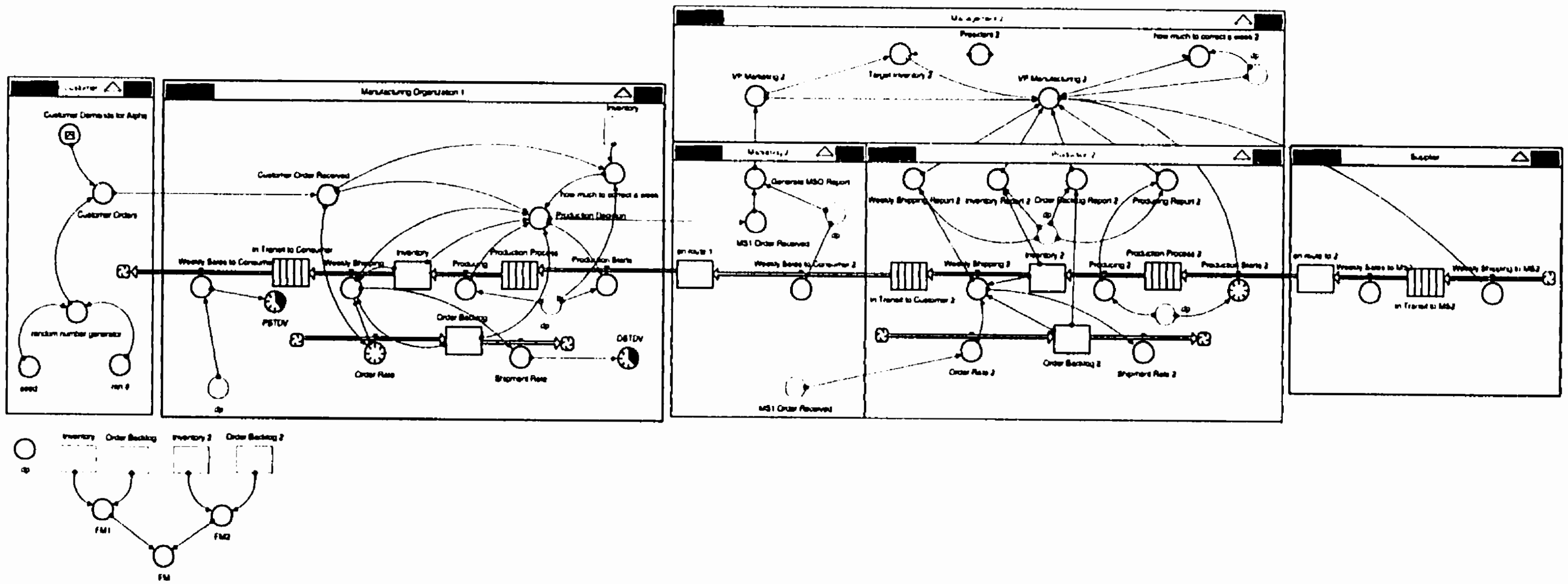
Appendix 5.
24 *ithink* Extended Enterprise Models



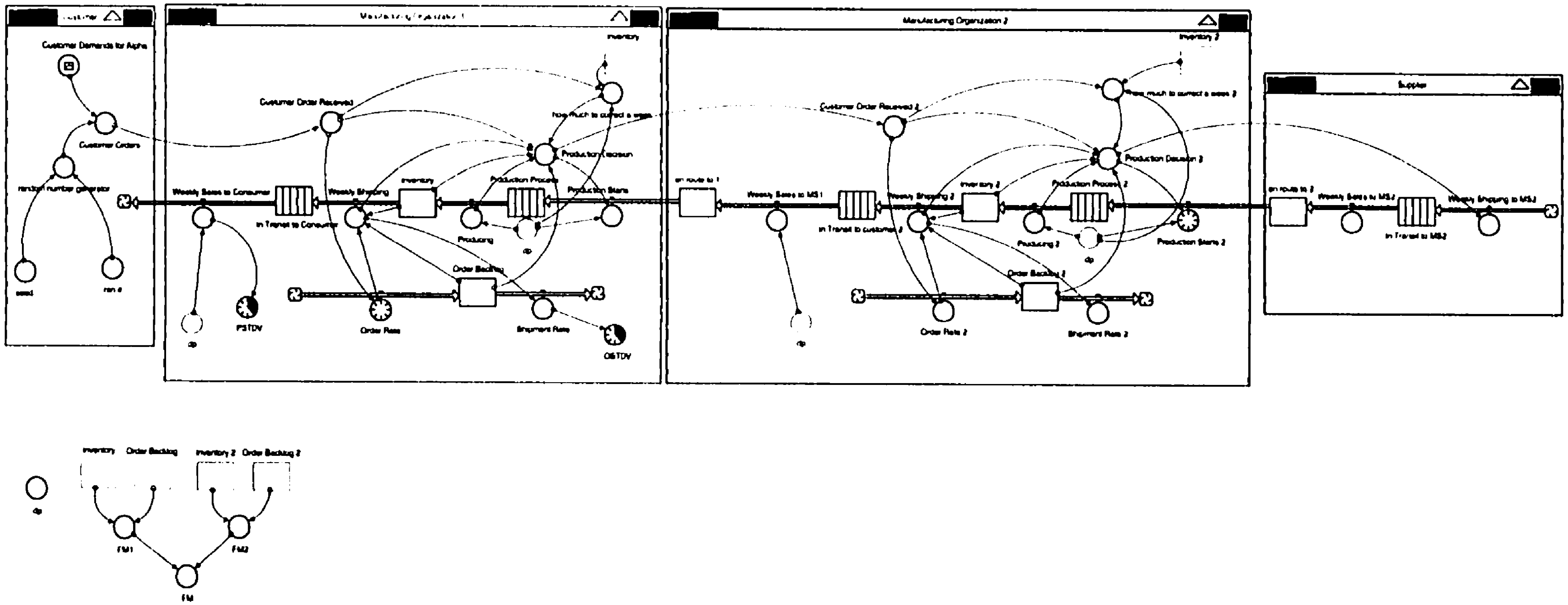
Appendix 5.1: 2MM



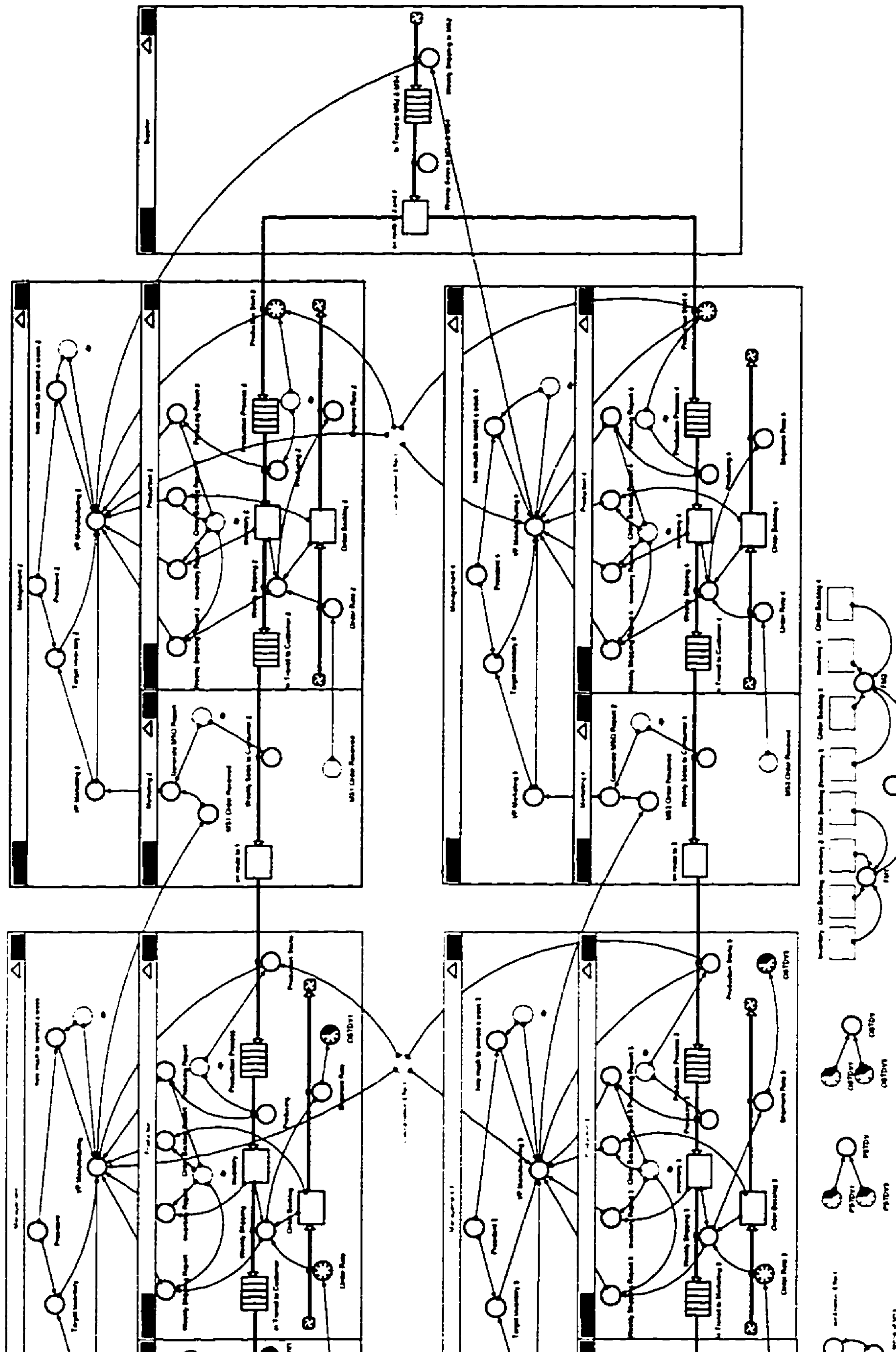
Appendix 5.2: 2MO



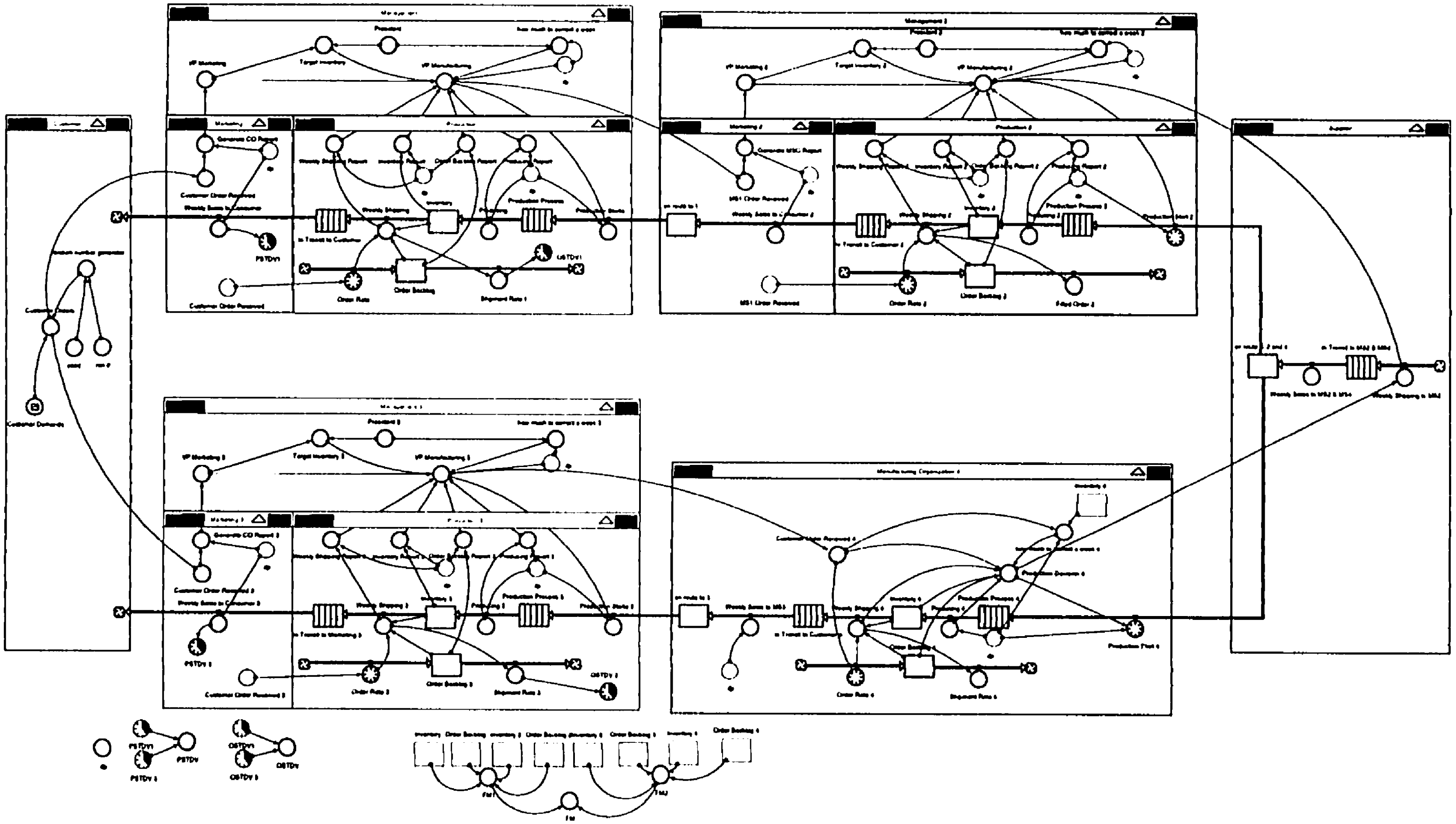
Appendix 5.3: 2OM



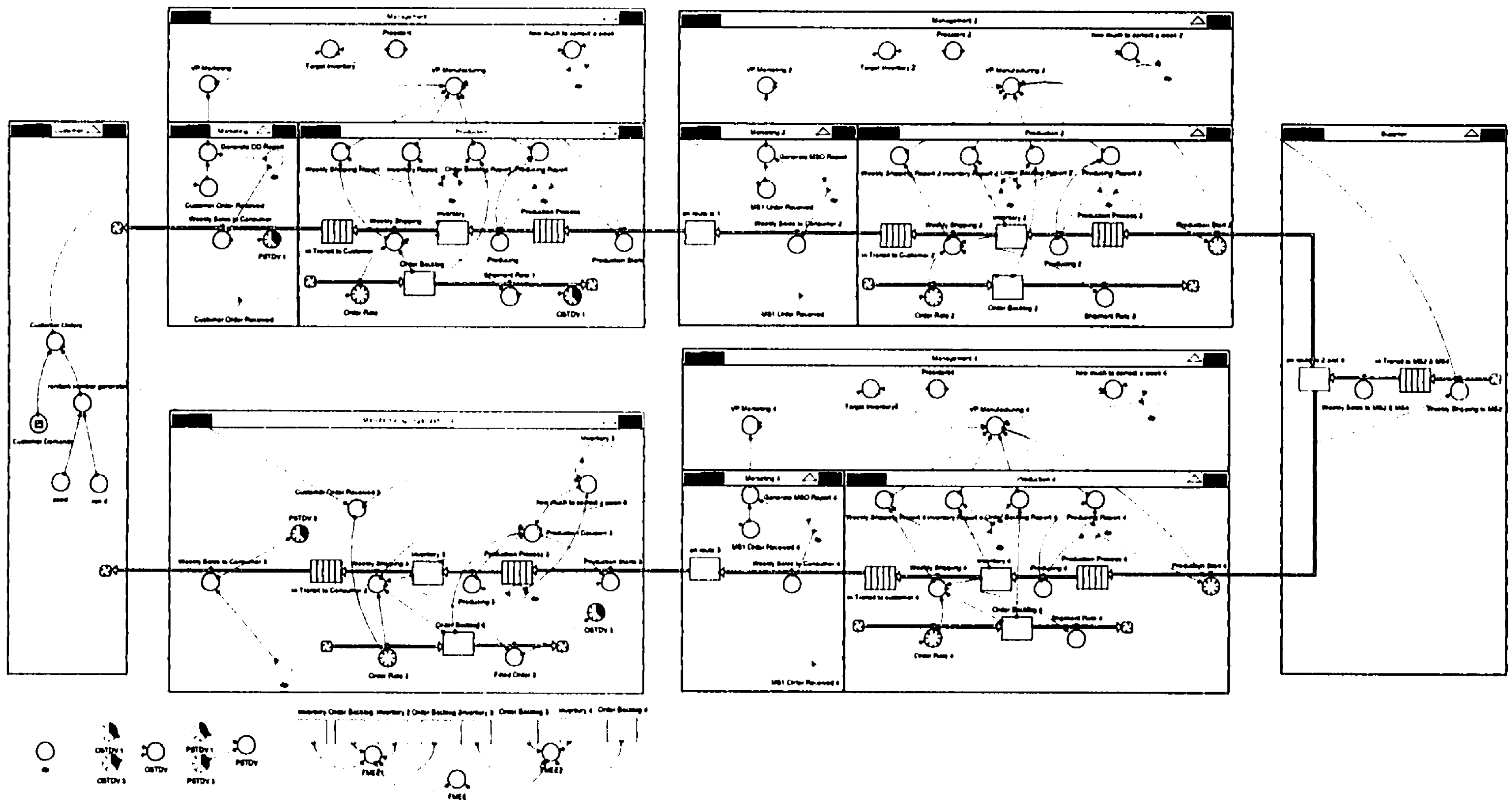
Appendix 5.4: 2OO



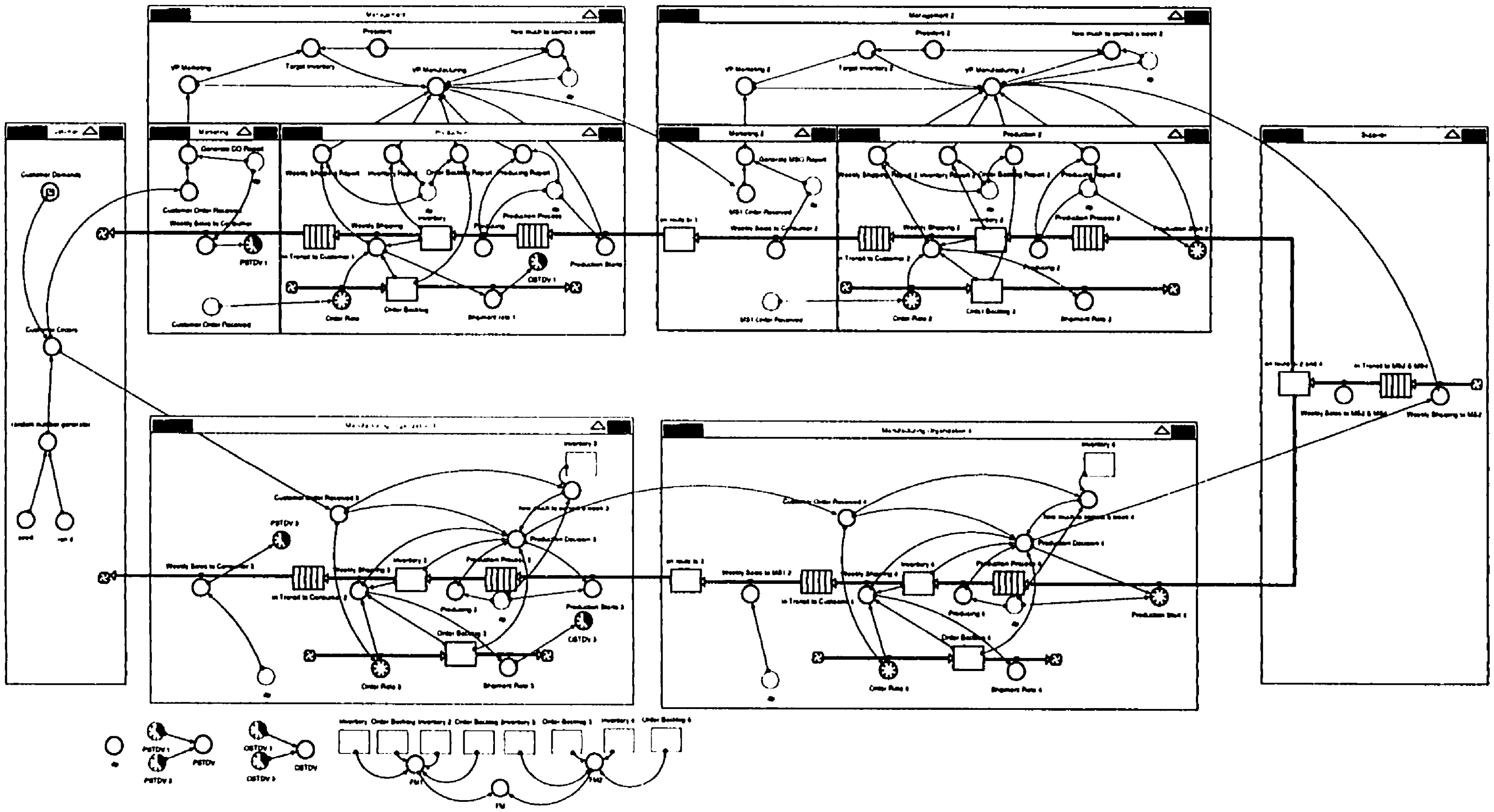
Appendix 5.5: SMMMM



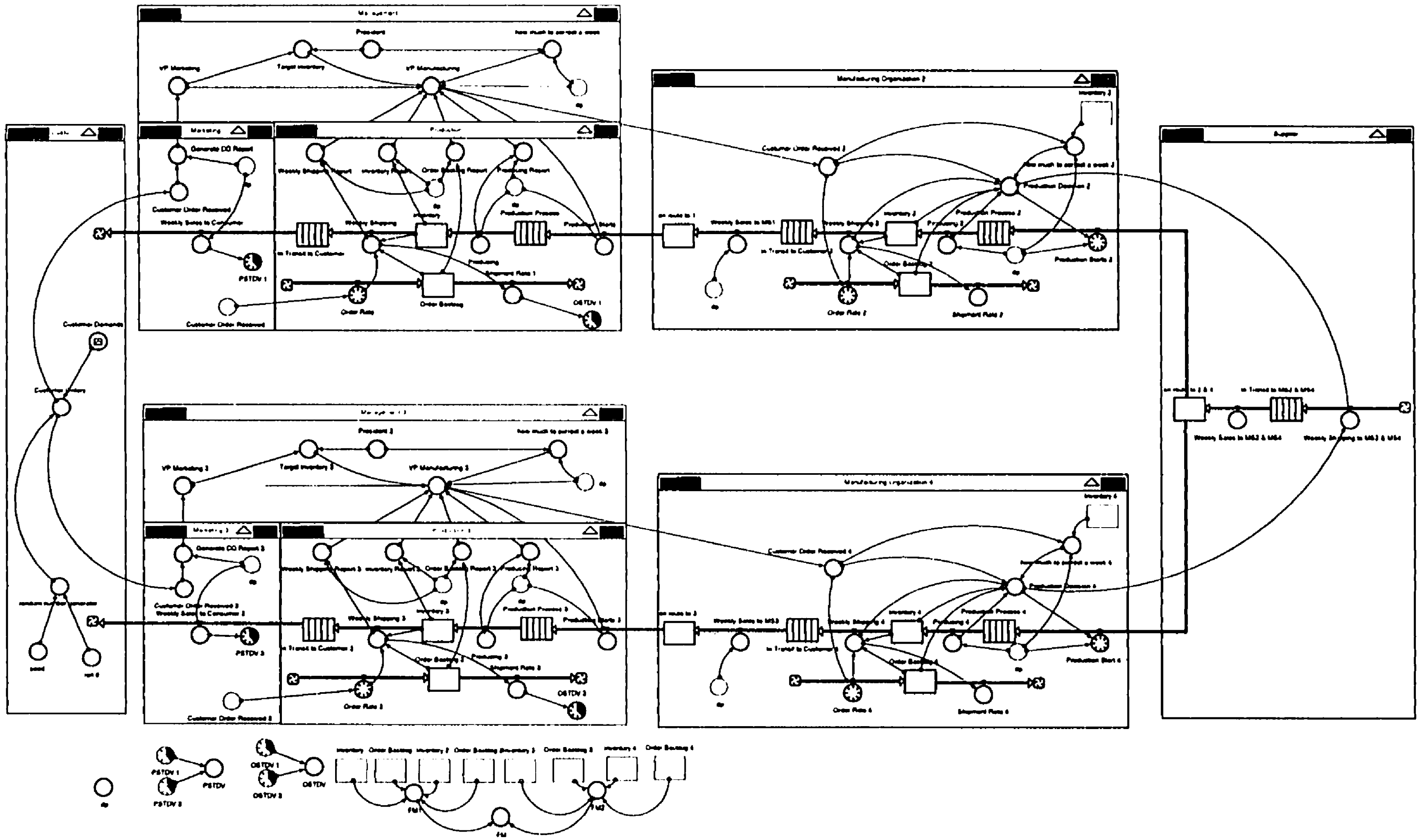
Appendix 5.6: SMMMO



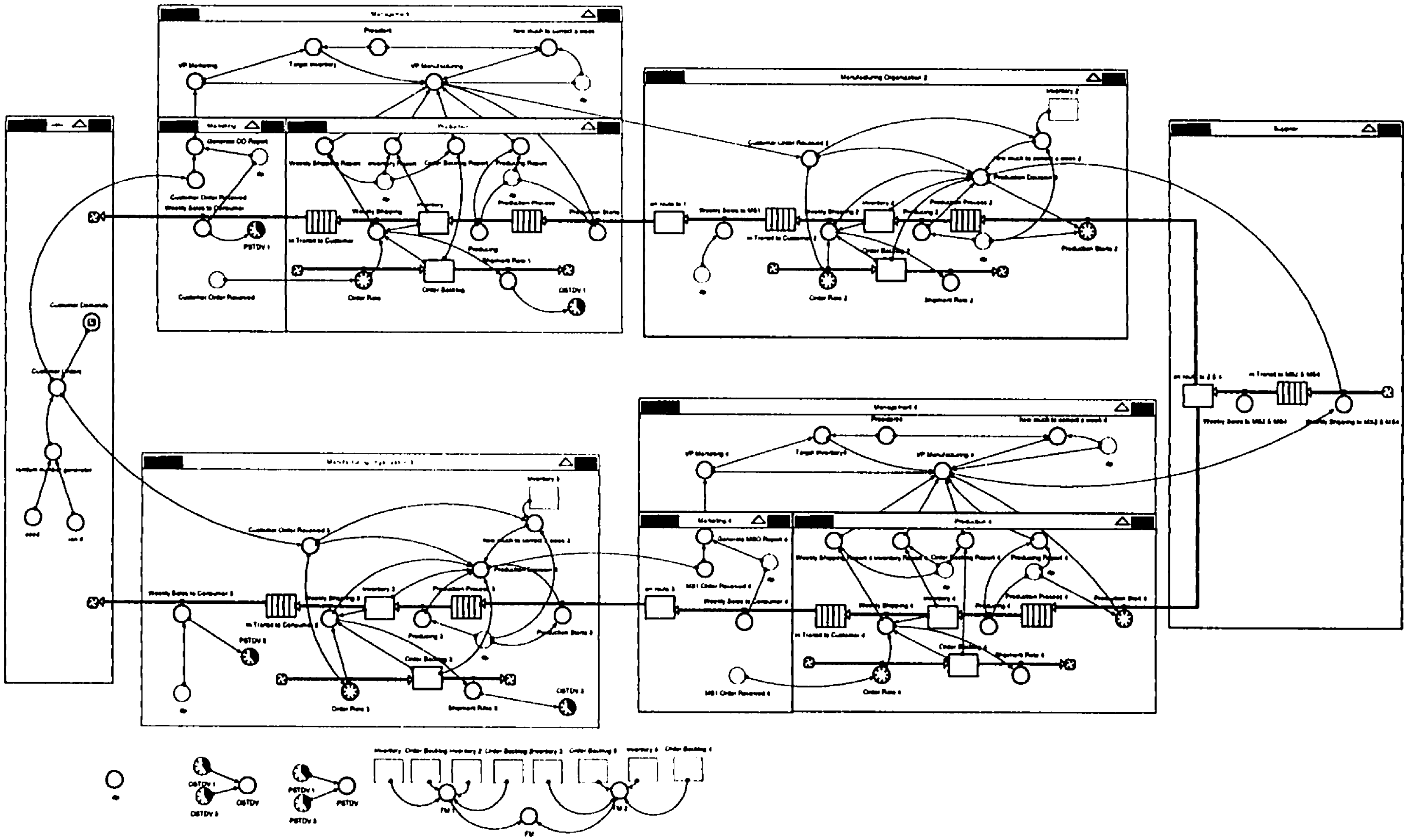
Appendix 5.7: SMMOM



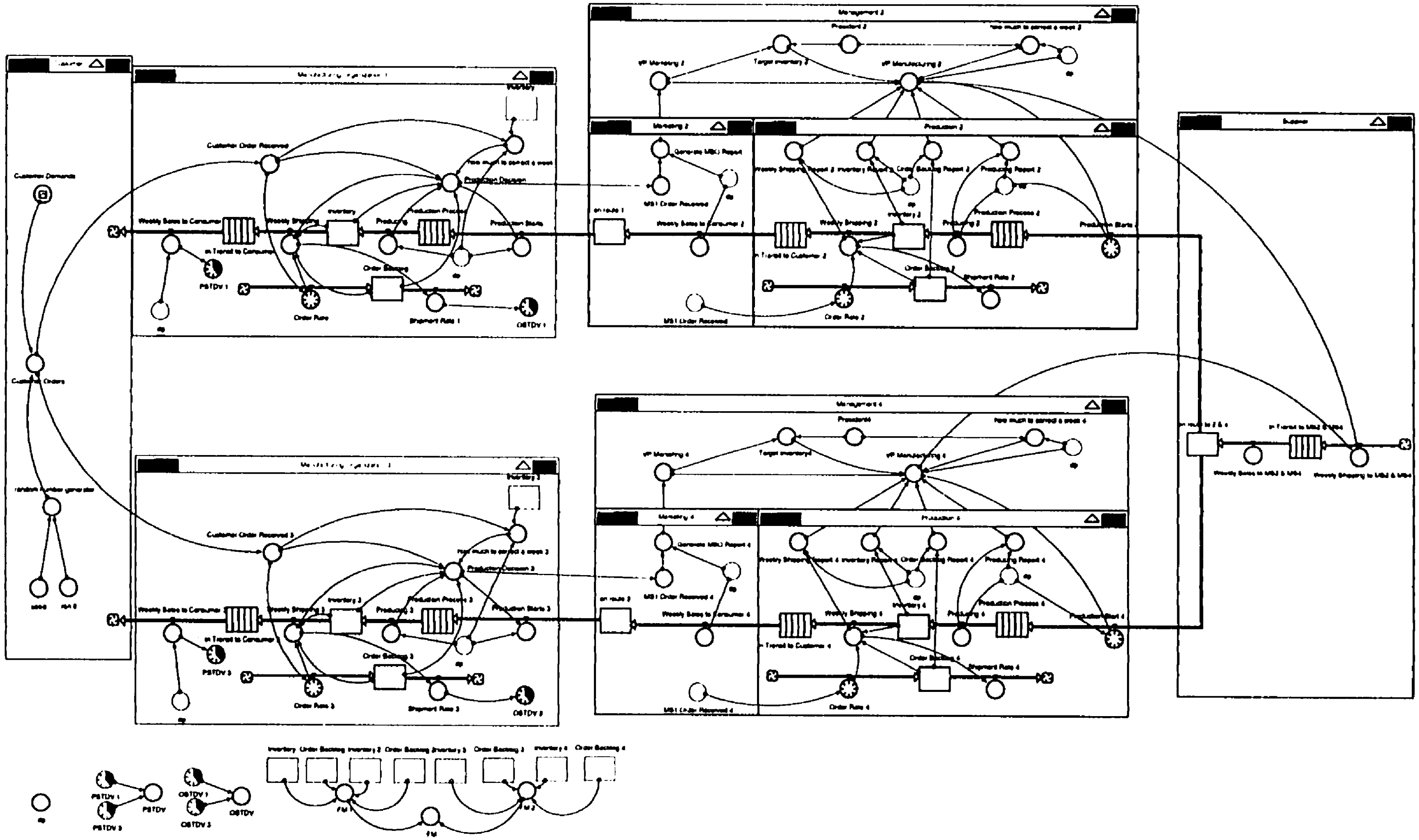
Appendix 5.8: SMMOO



Appendix 5.9: SMOMO



Appendix 5.10: SMOOM



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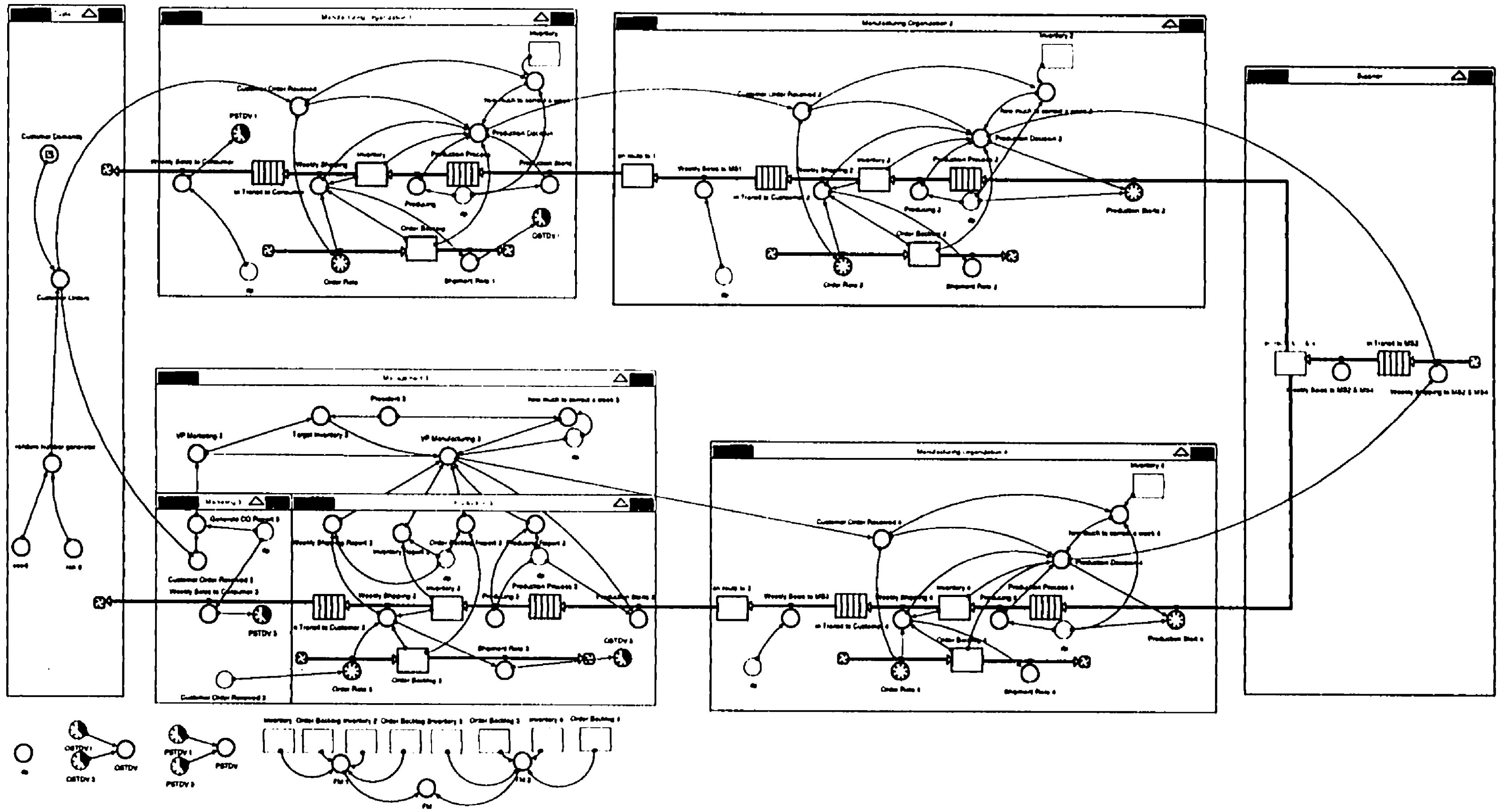
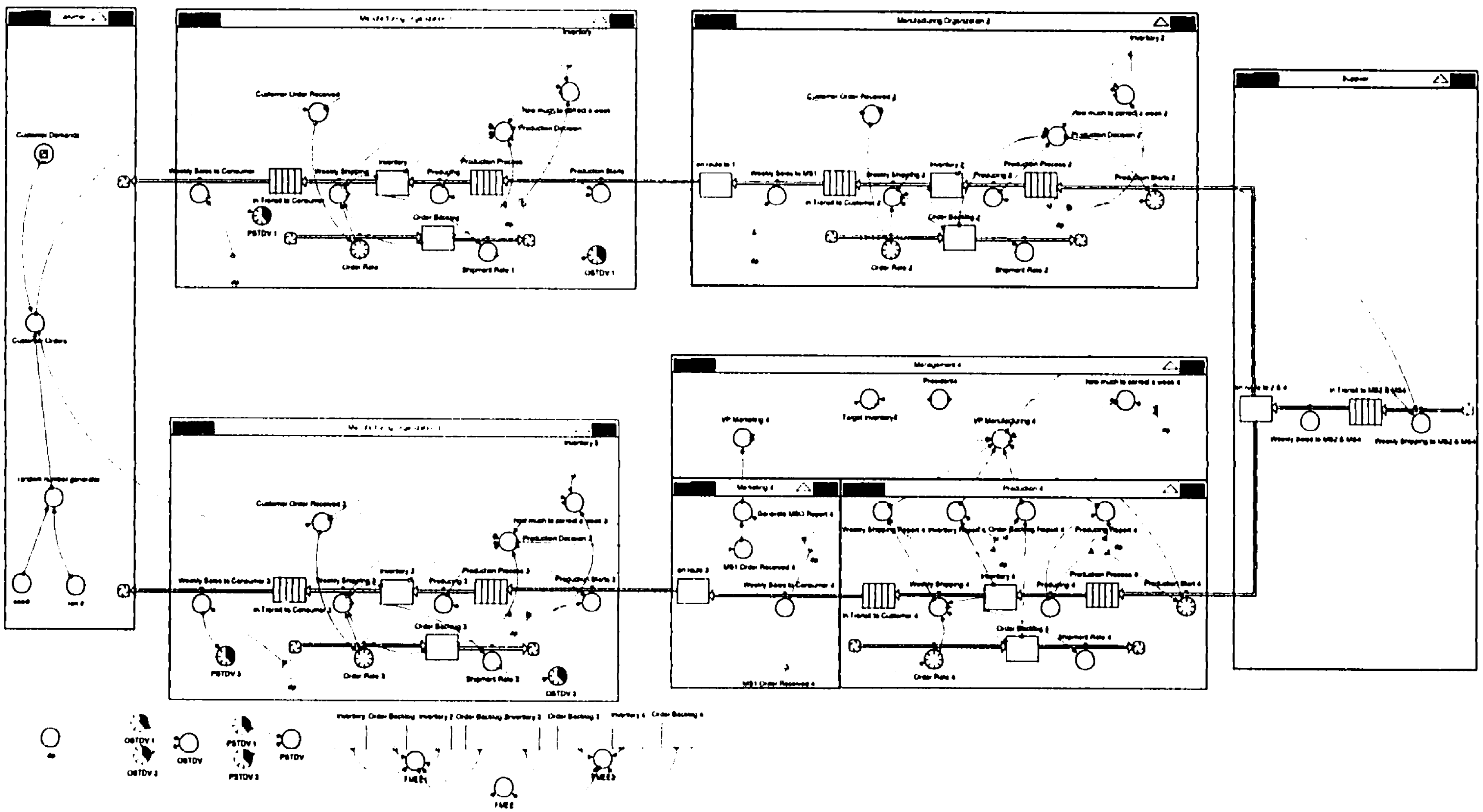


Appendix 5.12: SOOMO



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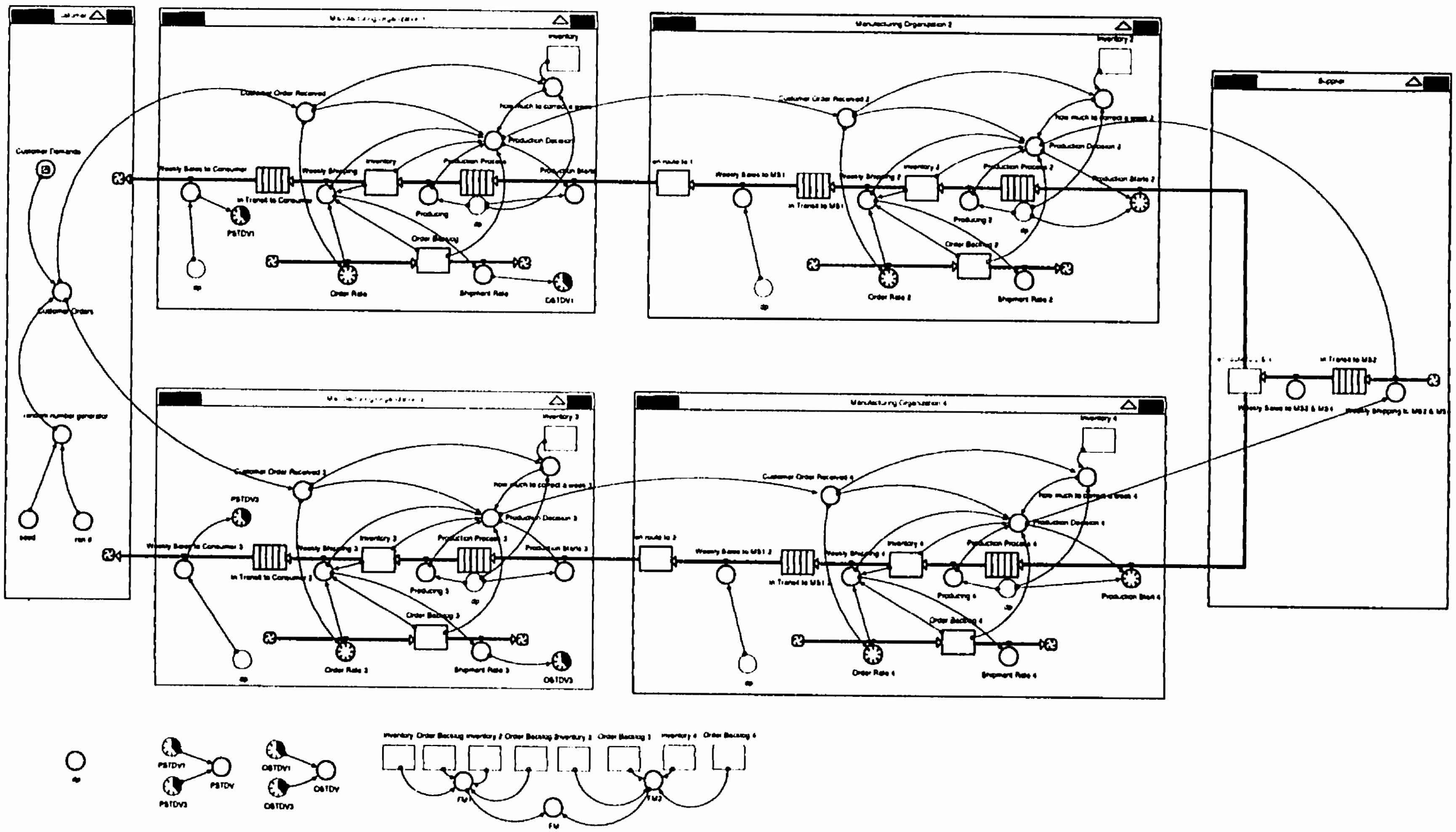
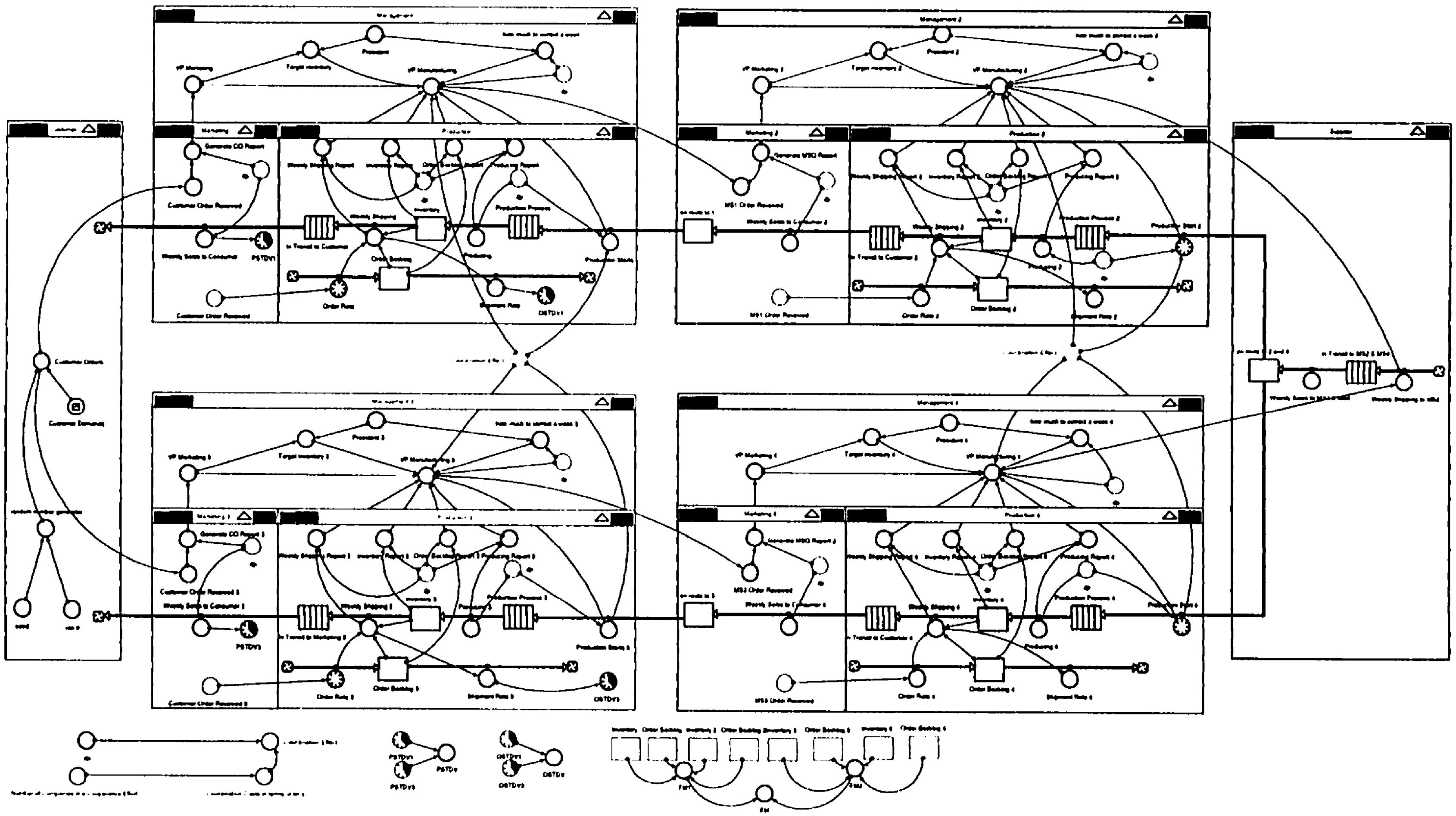
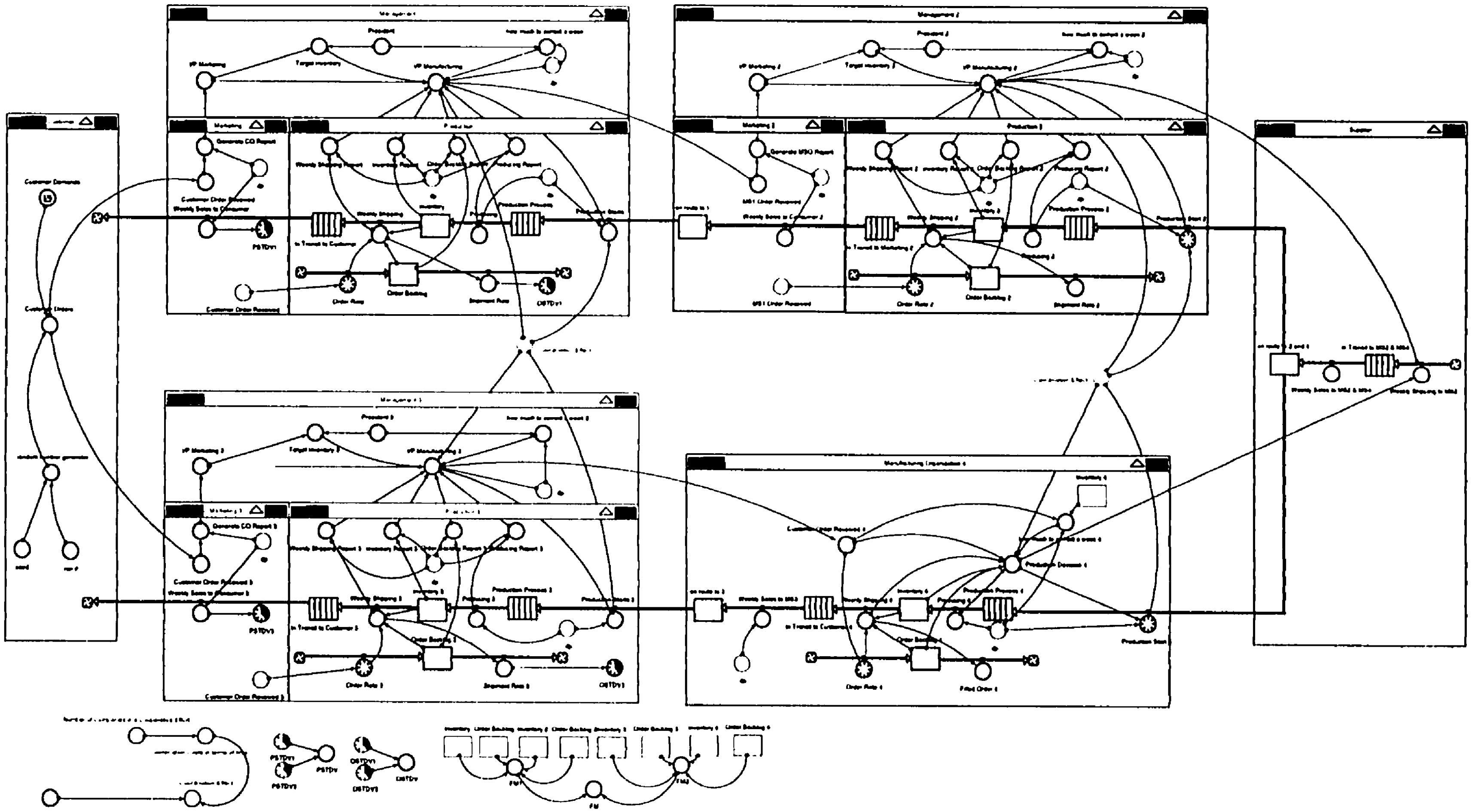


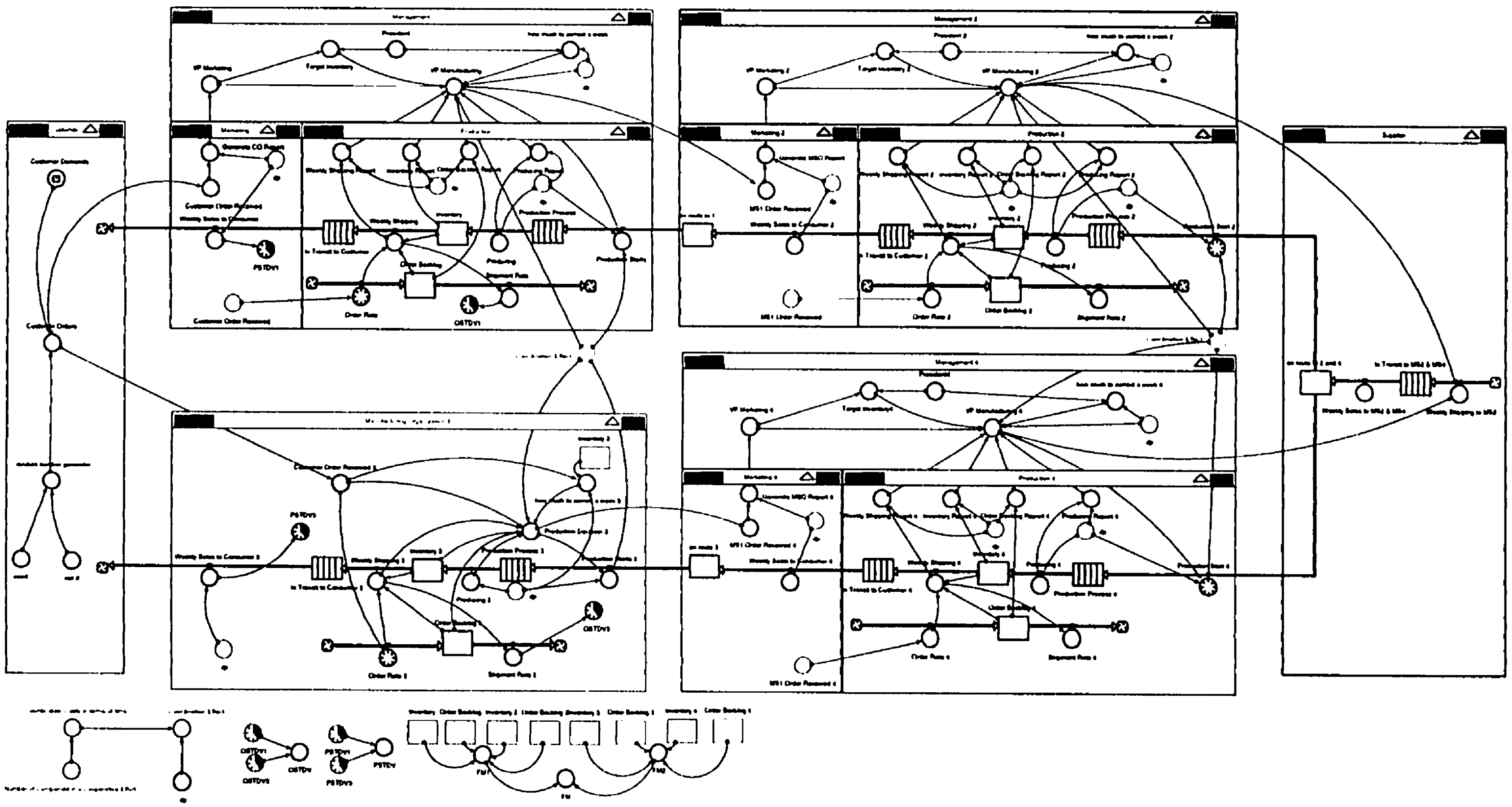
Appendix 5.14: SOOOO



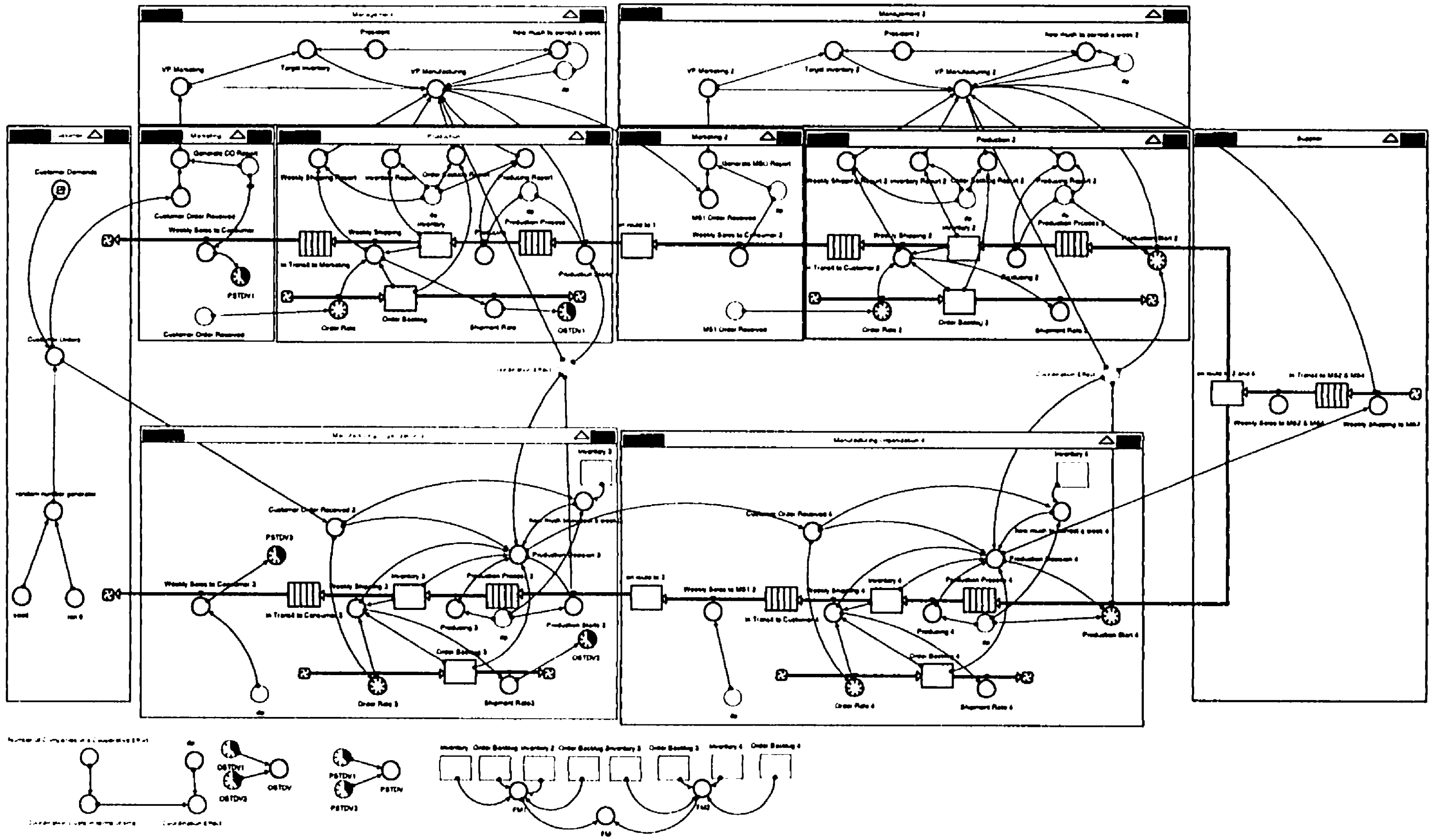
Appendix 5.15: RMMMM



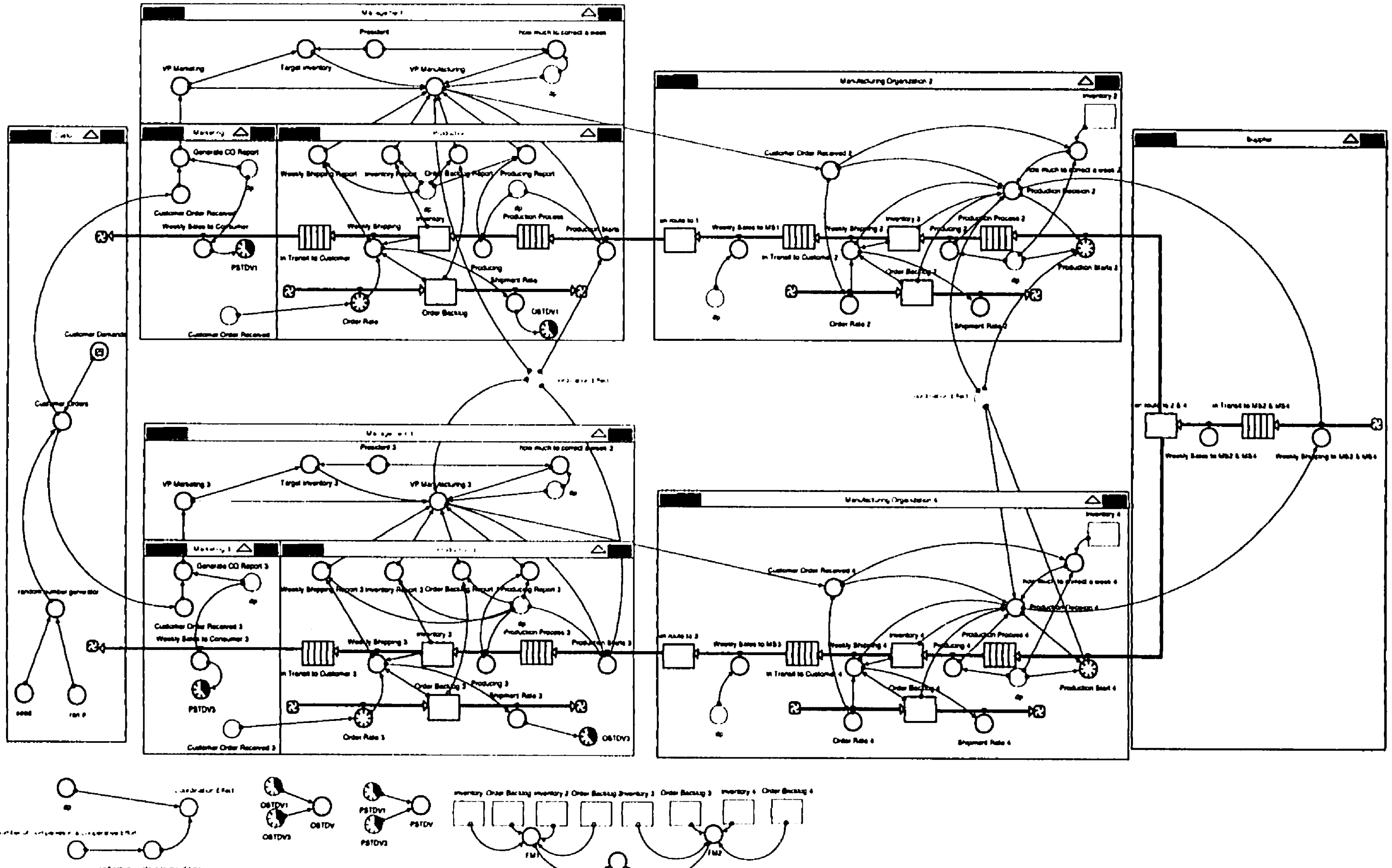
Appendix 5.16: RMMMO



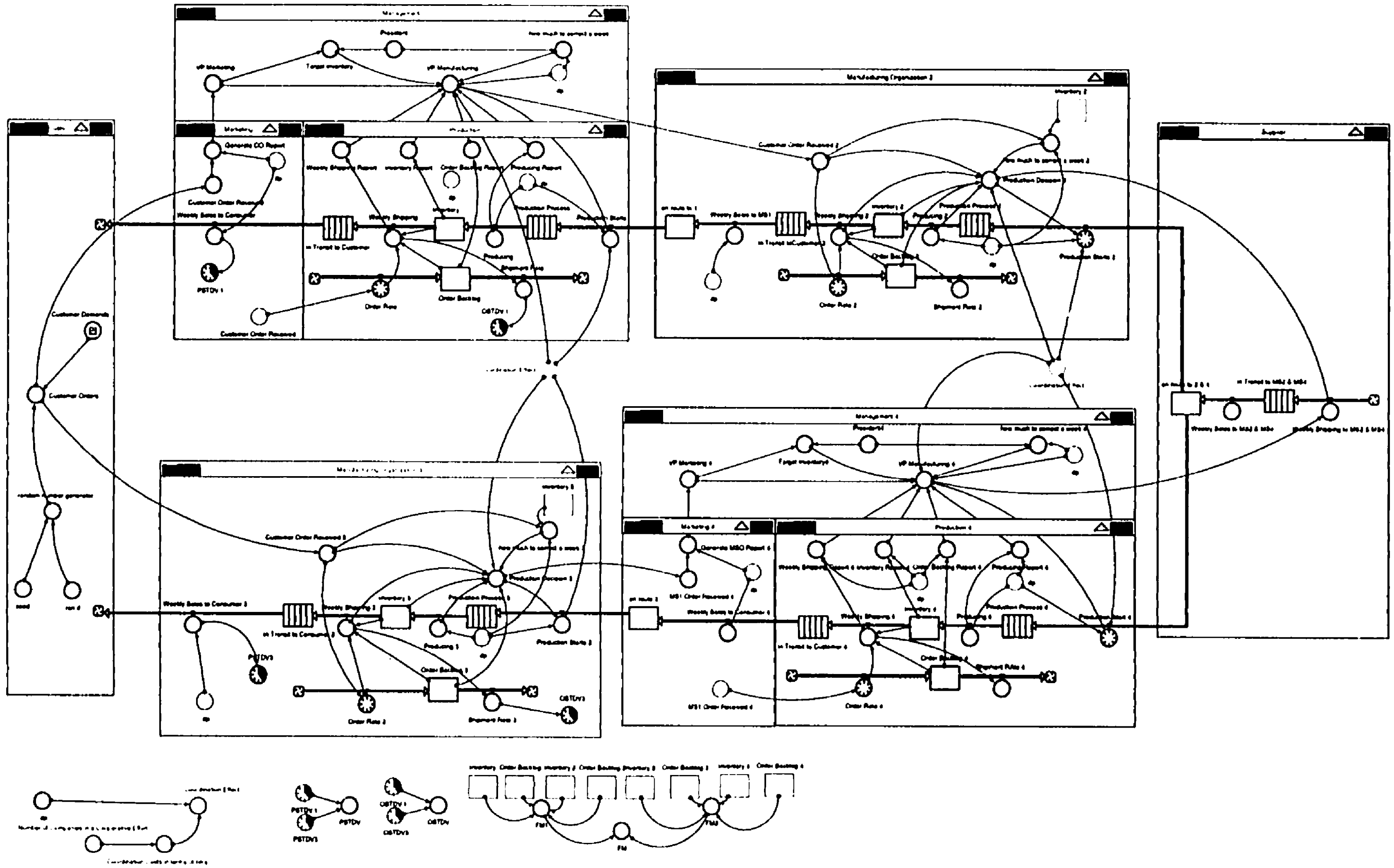
Appendix 5.17: RMMOM



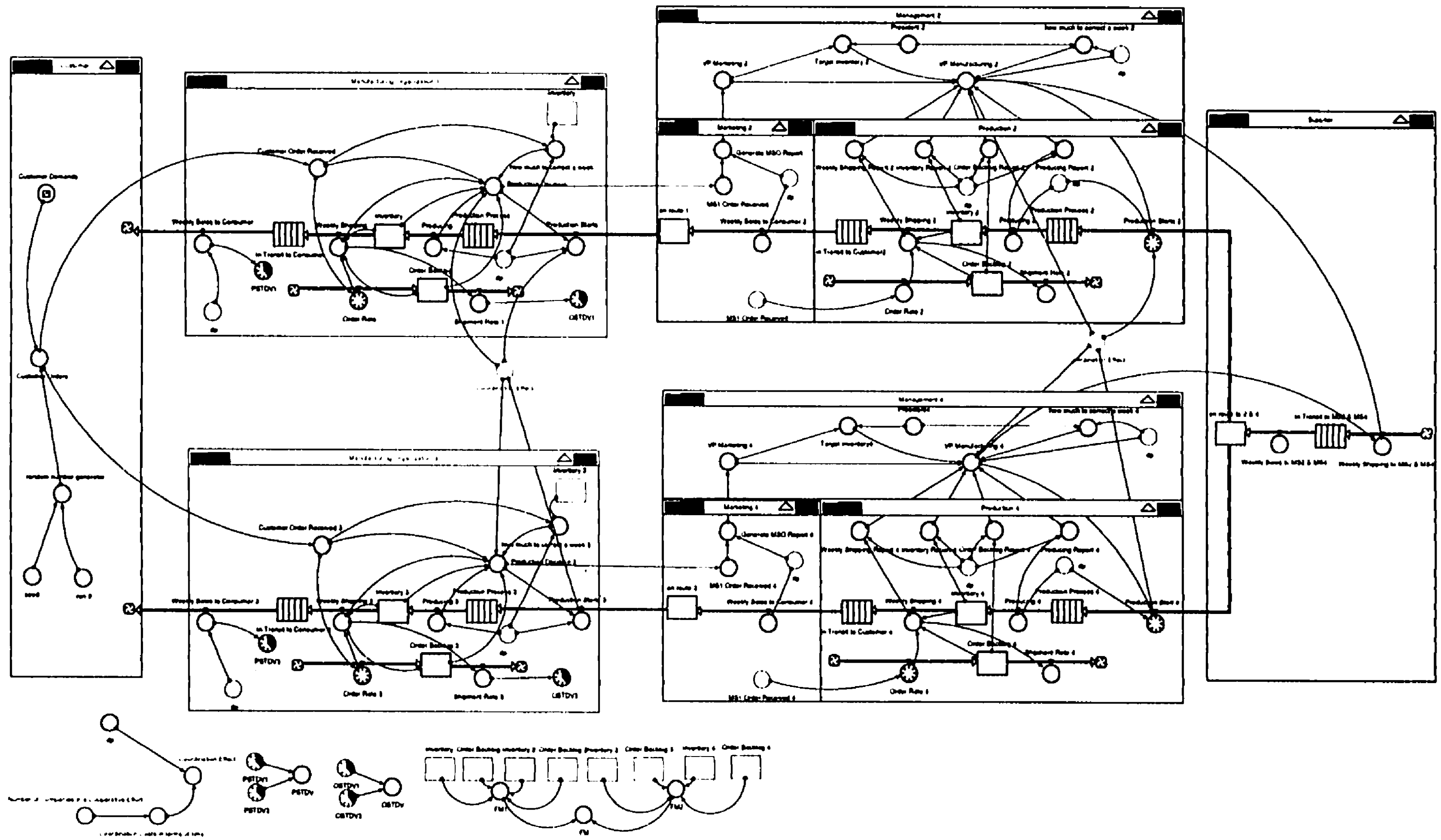
Appendix 5.18: RMMOO



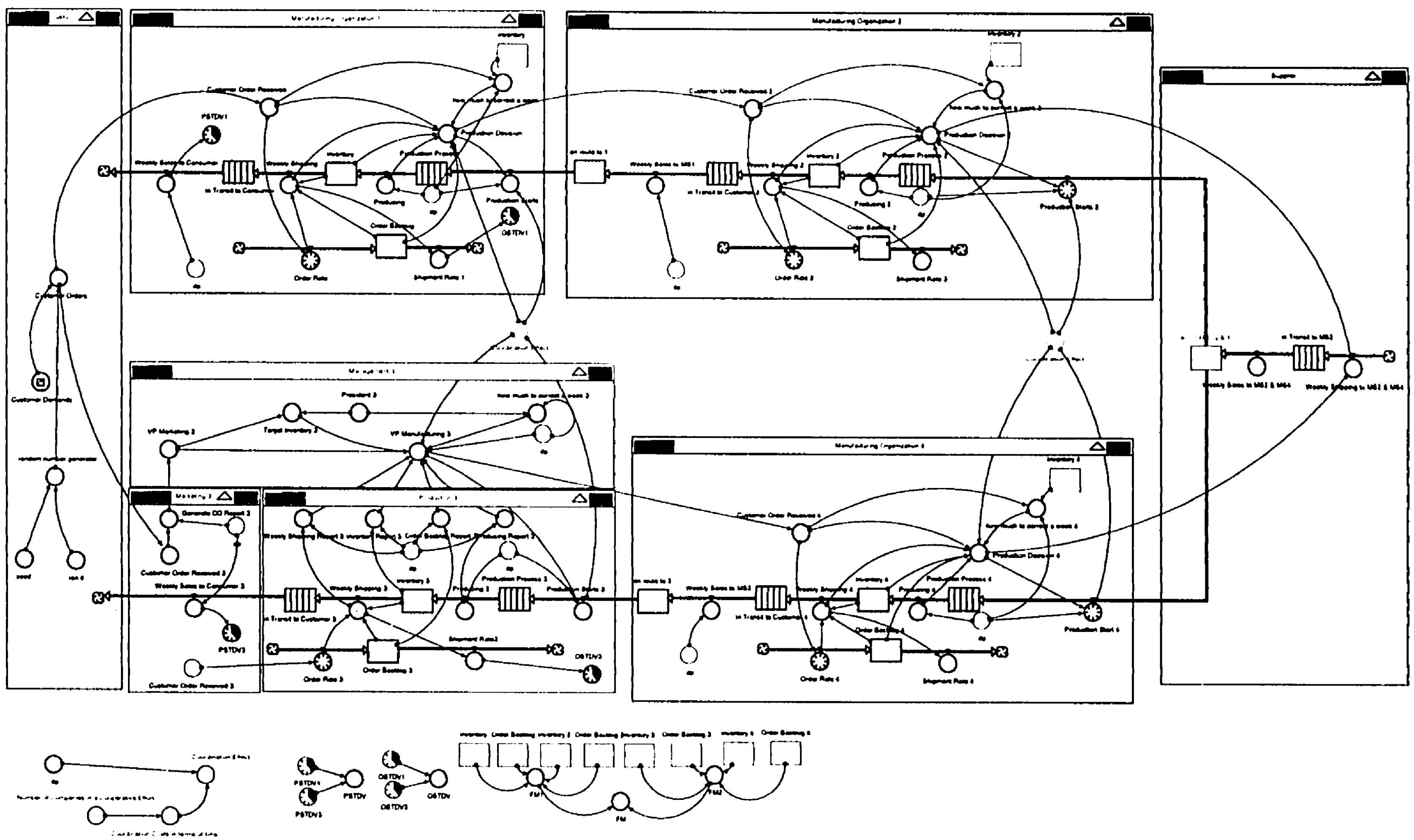
Appendix 5.19: RMOMO



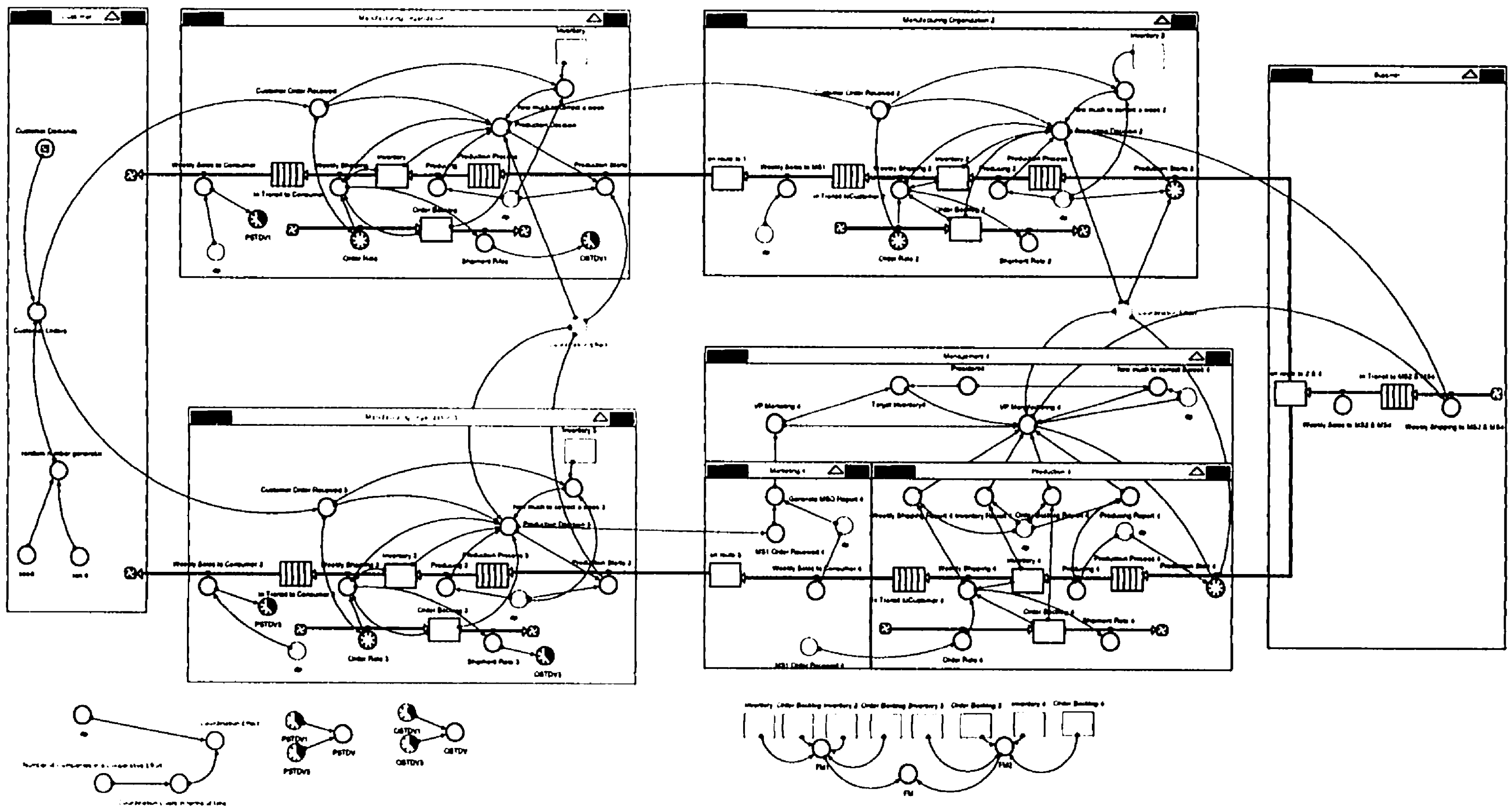
Appendix 5.20: RMOOM



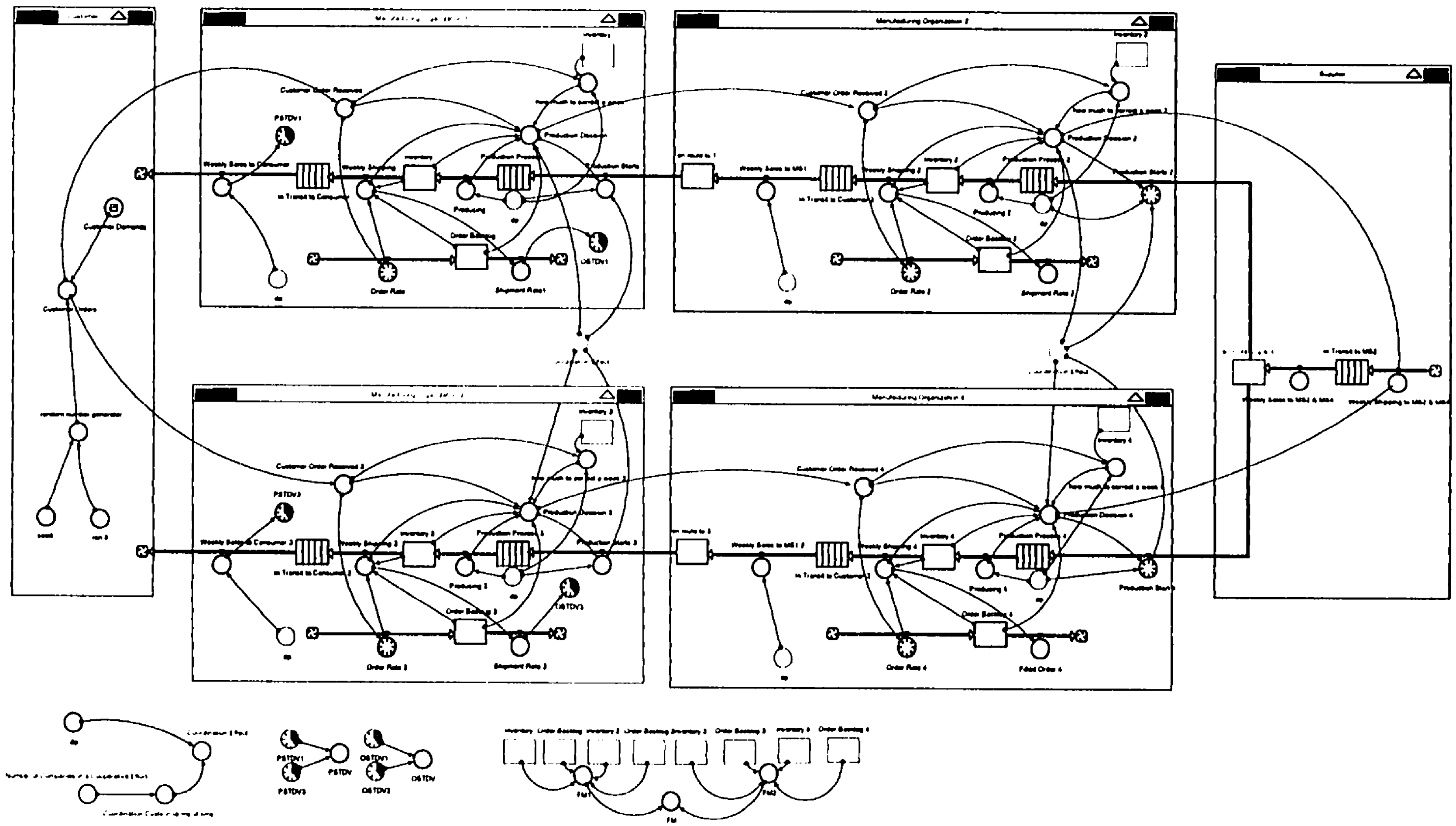
Appendix 5.21: ROMOM



Appendix 5.22: ROOMO



Appendix 5.23: ROOOM



Appendix 5.24: ROOOO

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