Design and Implementation of a Supply Chain Management System at an Emerging Optical Networking Component Supplier

by
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B.S. Mechanical Engineering
Washington University, 1995

Submitted to the Department of Mechanical Engineering
and the Sloan School of Management in Partial Fulfillment
of the Requirements for the Degrees of

Master of Science in Mechanical Engineering
and
Master of Science in Management

at the
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June 2002

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Abstract

Giga, located in Copenhagen Denmark, designs and manufactures circuits for optical networking systems. Like many optical networking component suppliers in the late 1990 and early 2000, Giga grew rapidly, and increased product volumes, head count and revenue by ten fold in only two years. This growth however occurred with little infrastructure in place to support the explosion in orders. This work will describe the development and implementation of a Supply Chain Management system to support Giga's emergence as a high volume supplier. The focus will be on developing a system to meet the needs of a startup-manufacturing firm. The work will demonstrate the use of a novel three-phase approach used to develop and implement a system in Giga. The implementation process covers a containment phase, a reliable system development phase and finally an advanced planning system phase. The work will also describe the design of a push/pull supply chain system, practical application of business process mapping to develop a repeatable system, and the modeling tools used to control the supply chain. The push/pull system, introduced in the second phase, allows the company to minimize inventory despite large demand variability and long fabrication lead times. Supporting the management of the supply chain are software tools that are used to manage the inventory counts and outstanding orders. This work will describe how these tools were modified to support the development of a more reliable and faster Supply Chain Management system.

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Executive Summary

Intel Corporation has begun to enter the communications industry as a supplier of integrated circuits and modules. On March 21, 2000 Intel acquired Giga. Giga, located in Herlev Denmark, designs and manufactures integrated circuits for optical networking systems, and became part of the Optical Components Division (OCD) of Intel's Communications Group (ICG).

Like many optical networking component suppliers in late 1990s, Giga grew rapidly, and increased product volumes, head count and revenue by ten fold in only two years. This growth however occurred with little infrastructure in place to support the explosion in orders. By 2001 the supply chain had grown to include dozens of suppliers and inventory points, with hundreds of unique products. The task of managing orders and inventory levels became unmanageable, taking weeks to return customer requests. In addition, large changes in demand in the industry caused major fluctuation in inventory. And finally, the data systems handling information on inventories were incomplete and inaccurate. These systems contained little information on product status and provided several opportunities for inventory to leave the system unchecked.

The challenge facing Giga was first the need to manage orders and inventory and second to turn their supply chain into a competitive advantage. This challenge had to be met at the lowest possible cost. Standard MRP/EPR systems would cost Giga a large percent of their current annual revenue and were therefore not an option. Standard MRP/ERP systems were also too large requiring additional overhead to manage them. As an emerging high volume supplier to the optical networking industry Giga needed to find a solution that would help streamline the supply chain, cut costs, cut turn time, and minimize inventory within their tight cost constraints.

This work will describe the development and implementation of a Supply Chain Management system to support Giga's emergence as a volume supplier from a custom build to order firm. The focus will be on developing a system to meet the needs of a startup-manufacturing firm. The work will demonstrate the use of a novel three-phase

approach used to develop and implement a system in Giga. The implementation process covers a containment phase, a reliable system development phase and finally an advanced planning system phase. The work will also describe the design of a push/pull supply chain system, practical application of business process mapping to develop a repeatable system, and the modeling tools used to control the supply chain. The push/pull system, introduced in the second phase, allows the company to minimize inventory despite large demand variability and long fabrication lead times. Supporting the management of the supply chain are software tools that are used to manage the inventory counts and outstanding orders. This work will describe how these tools were modified to support the development of a more reliable and faster Supply Chain Management system.

The three primary contributions to Intel from this work are (1), the use of a novel three stage approach of implementation, (2) the implementation of a push/pull supply chain design, and (3) the development of low cost easy to use Supply Chain Management system.

Acknowledgements

This thesis has been made possible through the help of many people and organizations. I would like to acknowledge the Leaders for Manufacturing Program for its support of the work and Intel Corporation and Giga for providing the environment and experience on which this work is based. I would like to thank the people at Giga for their support and advice during my internship, Randal Graham, Kenth Wrist-Jensen, Jennifer Nishimoto, Jon Frommelt, Kim Liu, Eric Damore, Jordan Plawner and Micheal Norrengaard. I would also like to thank the team from Intel Penang, Kumar Chaturbhuj, Hoon Hoon Heng, and Sok In Cheah.

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1 Integrated Circuit Manufacturing for Optical Networking Products

1.1 The Optical Networking Industry

In 2001 the optical communications hardware market was forecast by the Gartner Group to grow at a compounded annual growth rate of 41% to a total of $57.5B by 2004. Within this market Optoelectronics represented about $14.4B by 2004. Optoelectronic modules act as the interface between the optical and the electrical signals in an area network. The primary function of the module is to translate electrical signals to optical signals when moving from an electrical network to optical transmission and vice versa. The components in these modules and their forecasted market growth are shown in Figure 1.

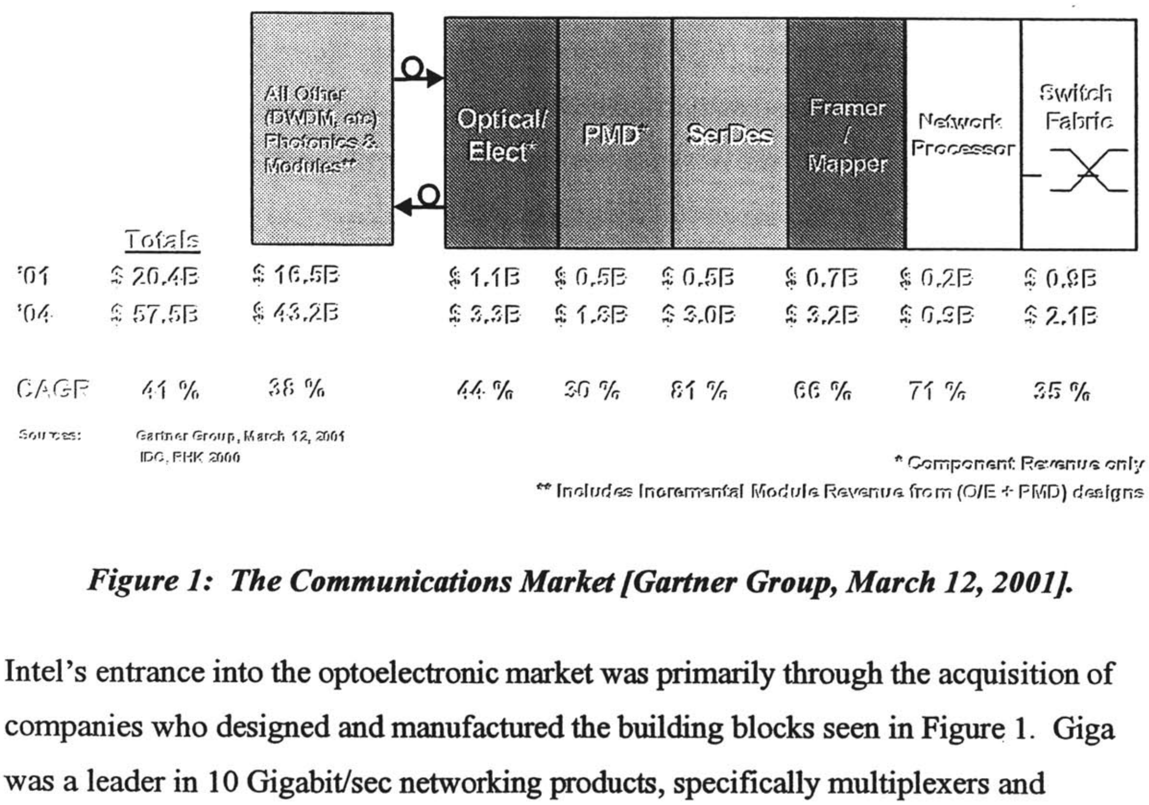


Figure 1: The Communications Market [Gartner Group, March 12, 2001].

Intel's entrance into the optoelectronic market was primarily through the acquisition of companies who designed and manufactured the building blocks seen in Figure 1. Giga was a leader in 10 Gigabit/sec networking products, specifically multiplexers and demultiplexers, serializers and deseralizers (SerDes in Figure 1), responsible for the combination and separation of signals before and after optical transmission.

The major companies in this market are Broadcom, AMCC, Lucent, and JDS Uniphase. Customers include Cisco, Marconi, Agilent, Nortel and again JDS Uniphase. The most recent trend in the market was the move towards more integrated modules. This trend was being driven by the complexity of the components and therefore the need for close coordination when building whole modules. Ultimately, instead of selling packaged die to customers like JDS, complete models would be sold.

1.2 Giga A/S (OCD), History and Background

1.2.1 History

Giga was founded by Finn Helmer in 1988 in Copenhagen Denmark. Since establishment Giga has developed, manufactured and marketed high-speed integrated circuits. These standard products are aimed at mixed and analog signal transmission within optical communications. In 1994 Giga introduced the first fully integrated 2.5 Gigabit/sec standard devices. In 1997 Giga was first to introduce a 10 Gigabit/sec transmitter in bipolar silicon and a 10 Gigabit/sec chip set in gallium arsenide. In 1999 Giga introduced the first ever 10 Gigabit/sec receiver in bipolar silicon and become a volume supplier. In 2000 they were volume producers of their third generation of 10 Gigabit/sec products. By 2000, through a supplier base, Giga had an annual capacity in excess of 10 million units. From 1999 to 2000 capacity grew by a factor of five.

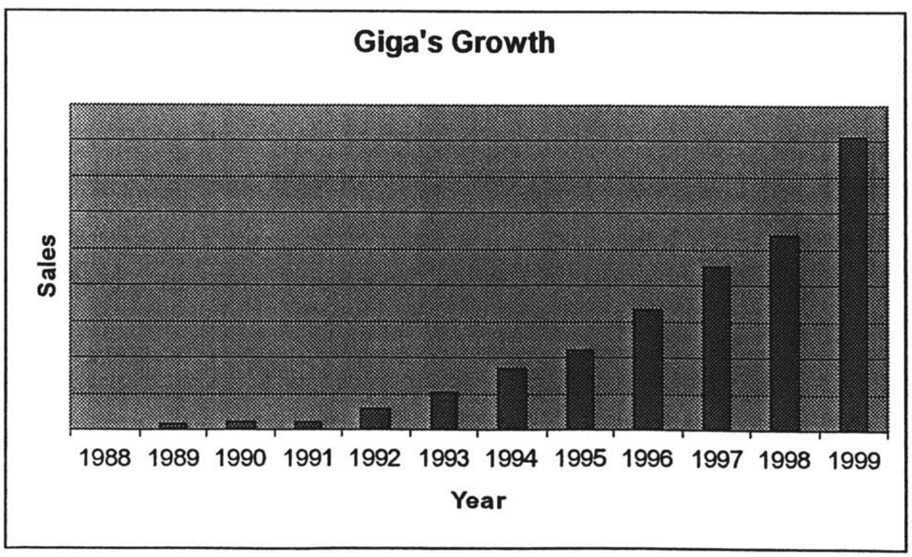


Figure 2: Giga's Revenues from 1988 to 1999

From 1993 to 1999 the compounded annual growth rate was 47%. Growth from 1998 to 1999 was over 50%. In the first quarter of 2000 reached record levels. Giga has research and development sites and offices in Denmark, Germany, the Baltics, and in North America in California.

1.2.2 Giga Organization

After Intel acquired Giga, it became part of the Intel Communications Group (ICG). During the writing of this work Giga was reorganized to various parts of ICG, finally being placed in the Optical Products Group (OPG) and was given the name Optical Components Division (OCD) and is shown in Figure 3. At the time of this work Giga had a large and dependent customer base for packaged die, and therefore remained fairly independent.

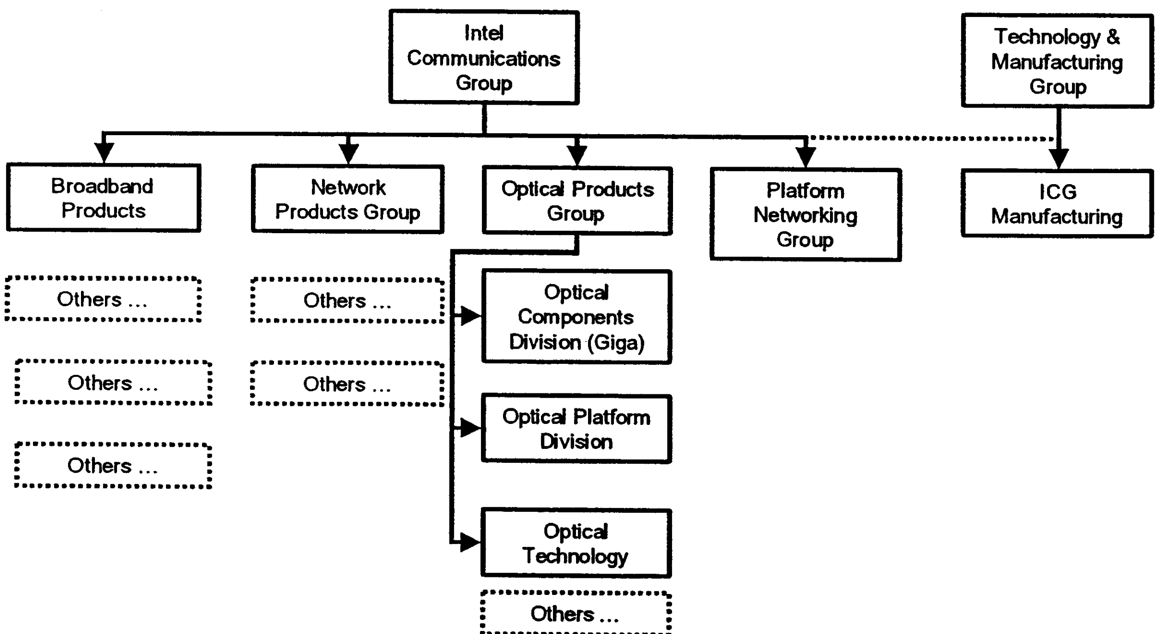
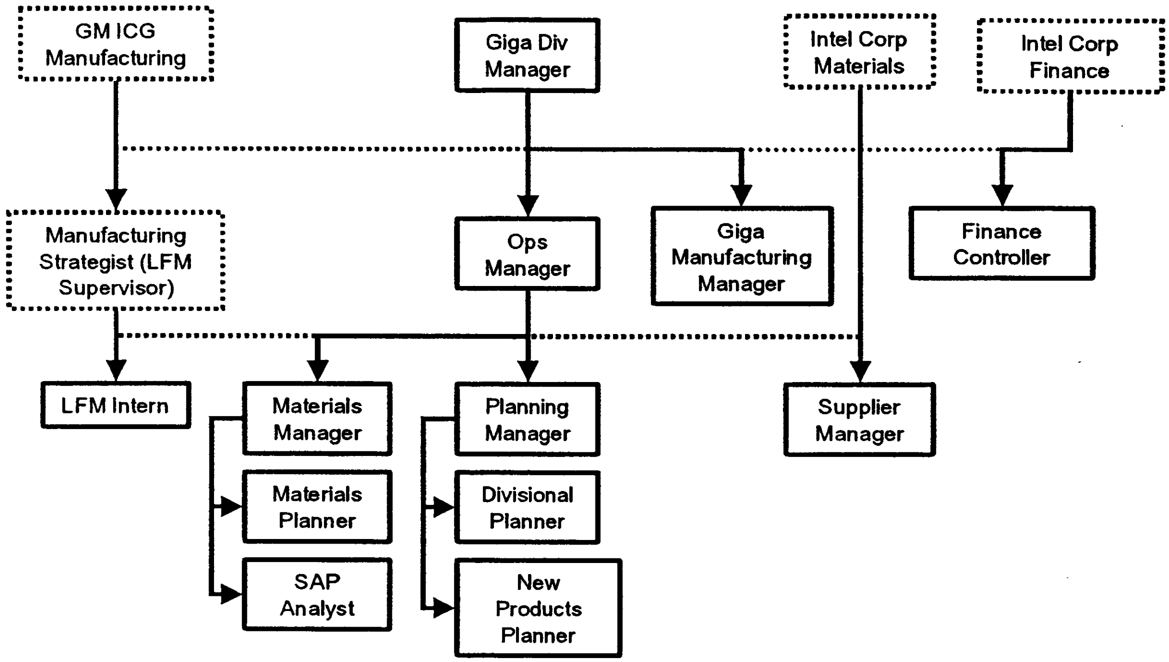


Figure 3: The Intel Communications Group Organization Chart

Although Giga now reported directly into the ICG organization individuals within Giga did not necessarily report directly to management in ICG. The manufacturing management from ICG, as well as the Finance, Capital Equipment and Human Resources reported only indirectly to the ICG VP. They also reported to either a corporate office or the Technology and Manufacturing Group that was responsible for running Intel's manufacturing operations. This shared reporting structure was also seen internally at Giga. This, I believe, was primarily driven by the need to balance corporate consolidation with regional control.



* Dotted lines; indirect reports. Solid lines; direct reports. Dashed boxes; US location

Figure 4: ICG/Giga Organization Chart

From my perspective the real control and responsibility was divided by geography. Relationships between all the members in the organization were very good. The goals and objectives of the ICG manufacturing GM were very much in line with the Giga Divisional manager. The dotted line management structure is very typical in Intel and everyone involved was generally familiar with this structure and comfortable having multiple supervisors. I also was managed in this structure, being responsible to both the Operations manager in Denmark and the Manufacturing Strategist in Oregon.

The Logistics Department was divided into two groups, Planning and Materials. The planning organization was responsible for converting demand forecasts into Wafer Fabrication, Wafer Sort, Assembly and Final Test orders. The Materials organization would then convert these requirements, based on inventory positions, to orders for the suppliers and issue Purchase Orders (POs). The roles and responsibility of the staff were as follows.

1. **Division Planner (DP)** – The DP is responsible for consolidating the forecast (Judged Demand) for ratification by the Division Management and for entering the data into the Division Build Plan model[1]. The DP is responsible for monitoring and tracking trends and orders through monthly forecast reviews, trending, tracking volume performance and delivery performance to schedule, prioritization, and highlighting issues to management.
2. **Supplier Manager (SM)** – The SM is responsible for the relationships with the suppliers. The SM must understand where the suppliers are moving in regards to technology, volumes, etc. The SM negotiates pricing and contracts and looks for new suppliers. The SM also handles business issues such as on time delivery problems.
3. **Materials Planner (MP)** – The MP deals directly with suppliers at the execution level. The MP is responsible for insuring that suppliers execute to the Supplier Build Plan. The MP is also responsible for buying piece parts to support the Supplier Build Plan. The parts are mostly dedicated to Giga production and special parts for a few suppliers.
4. **Finance Analyst** – Responsible for valuing inventory for the monthly budget that is used to calculate margins. Calculates reserves. Scrutinizes procurement. Double checks ordering work. Questions the Judged Demand from a financial perspective.
5. **Giga Factory Planner (FP)** – Responsible for the daily execution of internal demand, mostly test.

[1] The Build Plan Model was an Excel based tool used to managing orders. It will be described in more detail in Section 1.2.3.4. Excel is registered trademark of Microsoft® Corporation

1.2.3 Giga Supply Chain

1.2.3.1 The Supply Chain

Prior to the writing of this work the supply chain had grown to be complex with varying degrees of control and management. The manufacturing of product was outsourced for almost all high-volume production and for much of the new products in development. All products follow the same basic flow, which is common to all integrated circuits (ICs) manufactured today. First individual ICs, commonly referred to as die, are manufactured on wafers[2] in Wafer Fabrication. Next the wafers are tested for good die in Wafer Sort. Following Wafer Sort the good die are cut from the wafers and packaged. This is commonly known as Assembly. Following Assembly the packaged die go through Final Test. Wafer Fabrication was outsourced generally to two vendors, Wafer Sort was handled internally with a single vendor providing some limited support, while almost all Assembly was handled by several external vendors. Final Test was handle both internally and externally. The supply chain as it was in 2001 is shown in Figure 5.

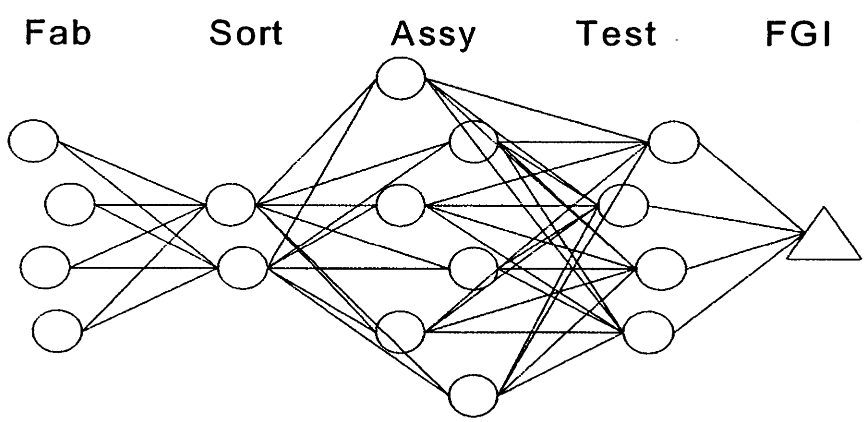


Figure 5: Supply Chain Nodes (FGI – finished goods inventory)

In addition to the large number of vendors, the flow of material was also more complex than expected for the relatively small quantities being manufactured. In a typical flow, product fabricated in Germany would be shipped to the Giga warehouse in Denmark then

[2] A wafer is the single unit of production used in the first step of IC manufacturing. A single wafer can be made up of thousands of individual ICs.

sorted internally in Wafer Sort or sent out again to a Wafer Sort supplier. Sorted wafers were again returned to the Giga warehouse, then sent to Malaysia for Assembly and then sent either to Giga for Final Test or to another Final Test supplier in Malaysia, before finally being shipped to the Intel central warehouse in Amsterdam to await customer delivery.

The complex supply chain architecture and the requirement for frequent shipping were further complicated by the lack of a single software system to track material or a single business process to follow when filling orders. The software systems were comprised of an ERP[3] tool called Navision, a factory control system call PCS (Production Control System) that had been built internally, and a dozen different Excel[4] tools and SAP.

1.2.3.2 The Supply Chain Business Processes

Three primary business processes were executed by the planning organization. There was a monthly process of loading new forecasts into the Division Build Plan model. There was the weekly process of reconciling the Division Build Plan content to insure that final test out requests matched actual customer orders. And whenever there were changes to customer orders, the orders in the Division Build Plan model were changed. These processes were not all apparent at the onset of the supply chain redesign project, but were discovered and documented as progress was made. The only apparent process at the beginning was the Build Plan Reset process.

Build Plan Reset: On a monthly basis marketing would publish an updated forecast of demand covering 8 to 9 months. The divisional planner would then load this new forecast into an Excel file called the Division Build Plan model. New build requirements for the suppliers were then calculated and sent to management for approval. Upon approval these requests were sent to the materials organization to recalculate orders based on inventory positions. The material planner would then issue purchase orders for demand due in four weeks.

---

[3] ERP refers to Enterprise Resource Planning

[4] Excel is a registered trademark of Microsoft® corporation

Demand Rationalization: To prevent orders from being fulfilled without customer demand, the SAP analyst would check SAP orders (booked) against the Judged Demand entered into the Division Build Plan model and initiate the cancellation of build request to the supplier if necessary. This was done for orders moving into the lead-time horizon.
Customer Order Changes: Whenever customers requested increases in existing orders (also known as upside) or new orders that were beyond the capacity stated in SAP the Giga materials group would be requested by the customer representative to determine feasibility. They in turn would contact the suppliers to check for extra capacity and then notify the customer representative of feasibility. This process took anywhere from one to two weeks.

These three processes were not always synchronized. In addition, not everyone involved in the planning process would be informed of changes needed to support one of these three processes. This was causing changes to be made to demand in the models without knowledge of everyone involved. Section 1.2.3.3 will describe, once an order has been approved, the process for executing an order.

1.2.3.3 Supply Chain Event Flow and Management

The business processes described in section 1.2.3.2 translated demand or forecasts into requests that were then sent out to the various suppliers. Once the requests were determined it was then necessary to execute these requests by issuing POs and inventory. To fully understand the baseline system the Supply Chain Management Team[5] created an event flow map showing what activities were necessary to completely move an order through the supply chain. This event map will be described in pieces. The following key shown in Figure 6 should be used to understand each flow diagram.

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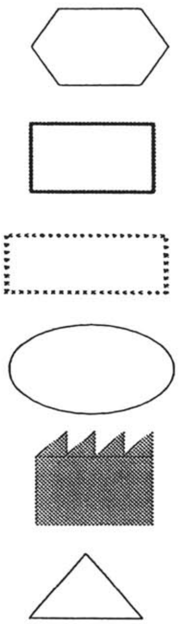
[5] The Supply Chain Management Team was formed early in the project and is described in more detail in Section 2.1.1



Navision activity

PCS activity

SAP activity

Other activity – for example receipt of goods

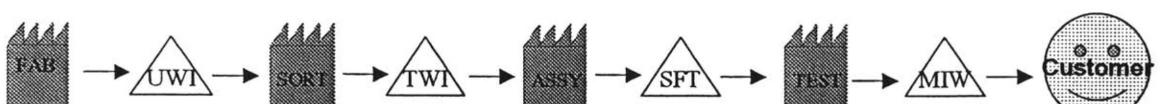
Manufacturing Operation, material as WIP

Inventory Location, material as inventory

MP – Materials Planner DP – Divisonal Planner
FP – Factory Planner MM – Materials Manager

Figure 6: Key to Event Flow Charts

A simplified flow map of the supply chain is shown in Figure 7. Figure 7 shows the path material follows, from Wafer Fabrication to the Customer. Between each step is an opportunity to hold partially finished goods.



[UWI: Unsorted Wafer Inventory, TWI: Tested Wafer Inventory, SFT: Staged for Test, MIW: Integrated Warehouse]

Figure 7: The Supply Chain Process Flow

Material is moved from Wafer Fabrication (FAB) to the Customer based on customer demand. The standard followed generally was to issue up to eight weeks of inventory to the Assembly (ASSY) suppliers who in turn would produce to a four-week schedule that was reset every week. Wafer orders were placed based on demand for new die. Each lot represented several months of inventory so orders were rare. The entire event flow is shown in Figure 8 and will be explained in parts.

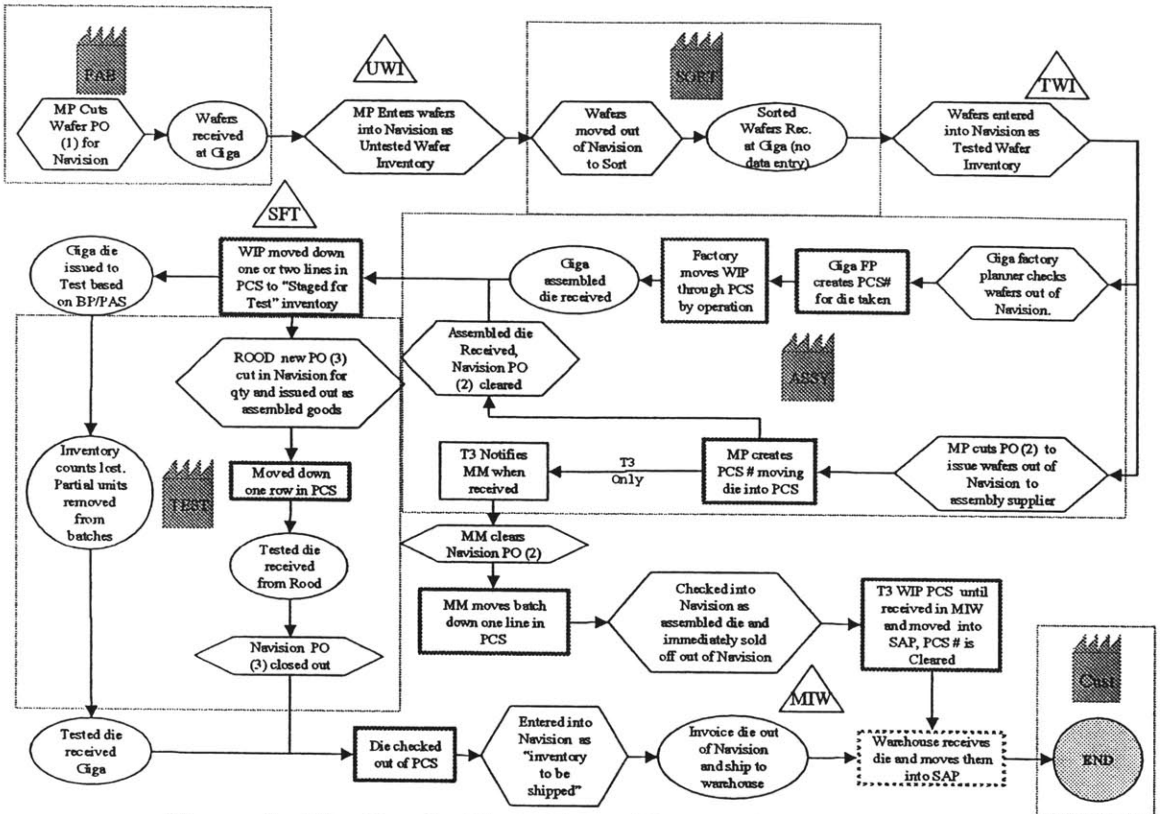


Figure 8: The Supply Chain Event Flow at the start of the work

The event flow for wafer movement was fairly simple. With approved orders the Materials Planner would issue POs and then receive wafers from the Wafer Fabrication Suppliers. The management of the data and material is shown in Figure 9.

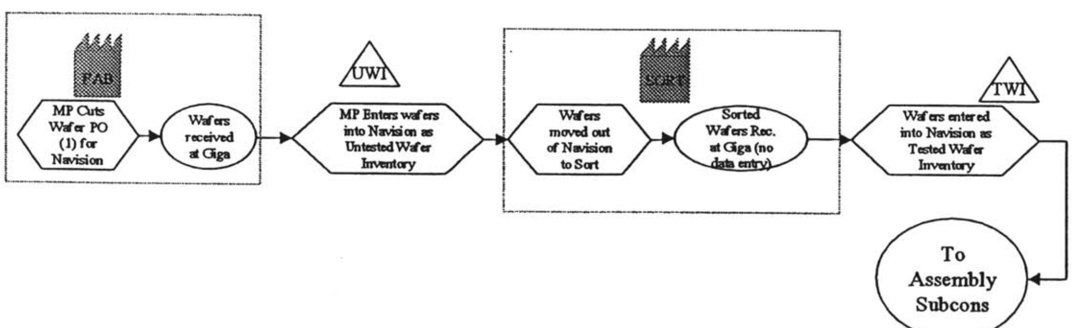


Figure 9: Event Flow from Fabrication to Tested Wafers

The first deviation in the process occurs when die are issued to assembly. Depending on whether or not the product goes to Giga or externally changes the management methods. For example if Giga is to receive and assemble the die then the factory planner checks out wafers from Navision, creates a tracking number in PCS and moves the material (WIP) through the system. If the die are sent out to be assembled then the MP creates a PO in Navision and a tracking number in PCS. Deviations such as the one just explained occur again when die are sent to be tested in Final Test as shown in Figure 10.

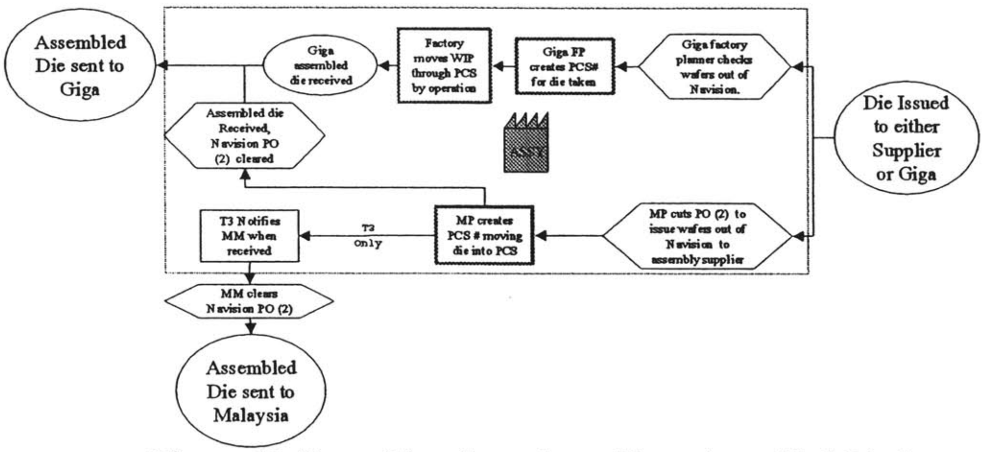


Figure 10: Event Flow from Assembly to Assembled Die Inventory

Next assembled die enter the Staged for Test Inventory and are sent to either Giga or Rood (a Wafer Sort and Final Test supplier) for testing or they go directly to a Malaysia supplier for testing.

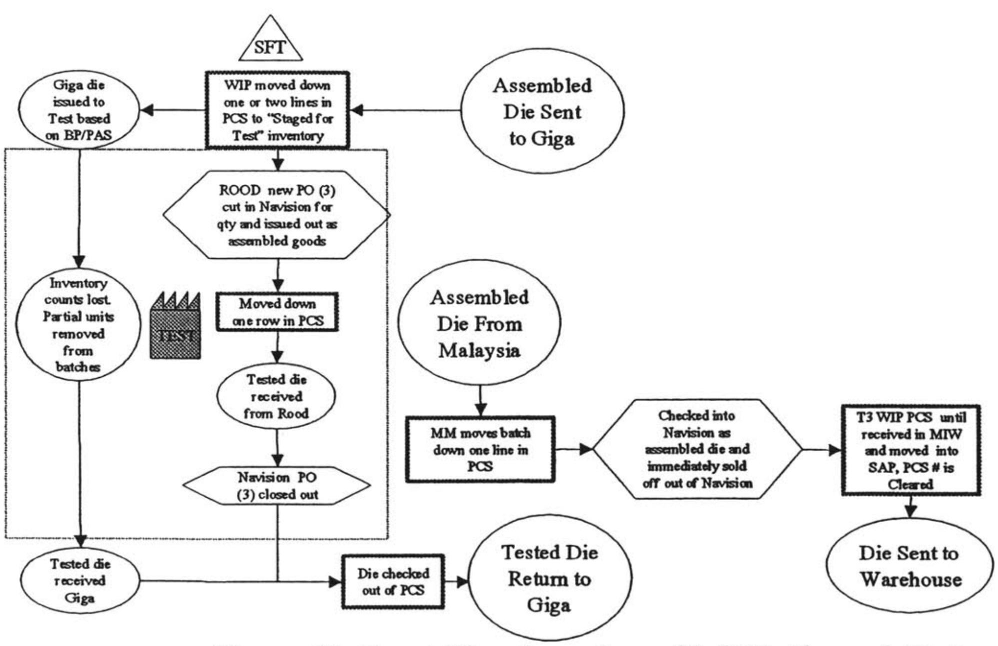


Figure 11: Event Flow from Assembled Die through Test

Finally tested die are moved to the consolidated warehouse, either from Malaysia, Giga or Rood.

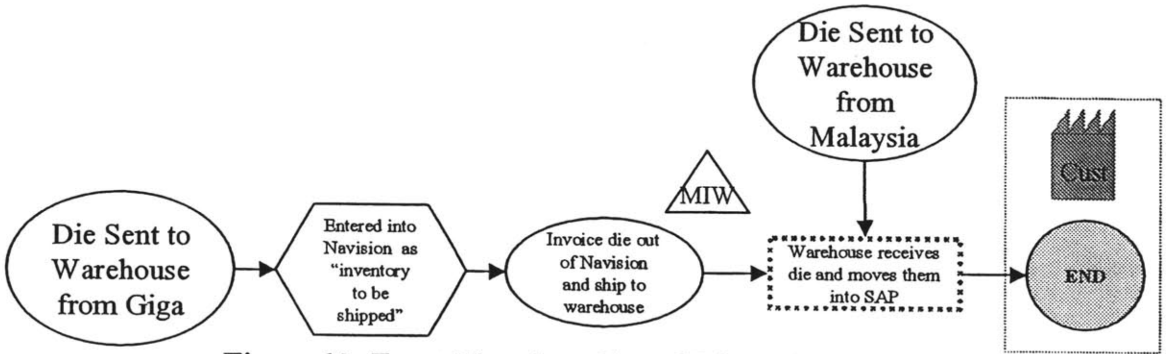


Figure 12: Event Flow from Tested Die to the Customer

1.2.3.4 Giga's Enterprise Resource Planning and Materials Resource Planning

Several systems supported the Supply Chain Management at Giga. One of the primary problems at Giga was the lack of connectivity of these systems. Following is a brief description of each system.

- **Production Control System (PCS):** This was a software system developed by Giga several years prior to this work. The system was developed to handle material flow, routes and inventory in the factory. In the current envi ronment it was also being used to supplement as an MRP tool, holding some inventory data on Wafer Sort and Giga Assembly and Final Test.
- **Navision**: Navision was an off the shelf ERP tool. The version used at Giga did not have the MRP module installed and was used to handle POs and in costing the inventory each month. It was also used as an MRP tool as it held inventory data, but not by design.
- **SAP**: SAP was the ERP system used by Intel. Giga's interface to SAP was limited to finished goods and in storing customer orders. Once material reached the warehouse it was entered into SAP. SAP provided the customer representative a picture of finished goods supply and could therefore confirm

orders from customers. Any upside beyond what was shown in inventory (which included a forecasted inventory) had to be approved manually.

- **Division Build Plan & Supplier Build Plan Models**: Giga also used a series of Excel based tools as an MRP system. The first was the Division Build Plan model that would convert demand into assembly and test requirements. The second were the Supplier Build Plan models that were used to adjust the requirements for each supplier based on inventory positions.

In addition to the number of exceptions that existed in the system the number of di fferent data tools used also increased the complexity and left room for error. The entire process flow in Figure 8 is shown again in Figure 13 but with respect to the data system reveals the level of software complexity.

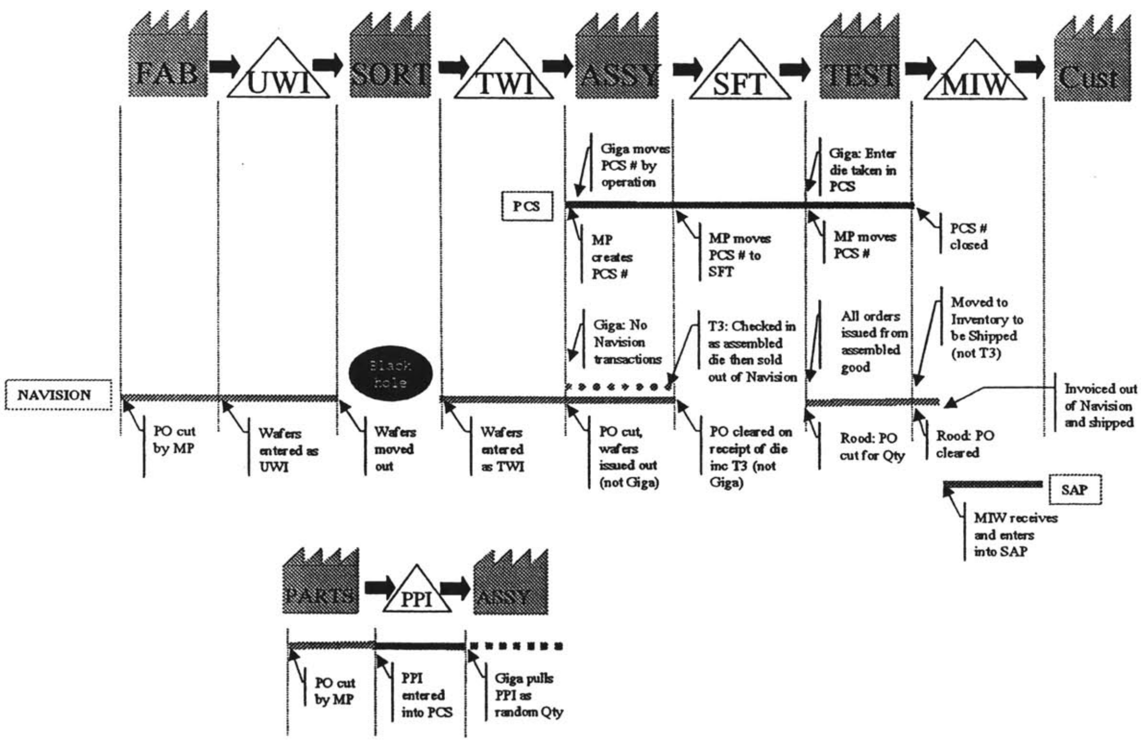


Figure 13: Data Entry for Material Management

Figure 13 describes each of the various software systems used. These systems, however, handled only the PO data, some inventory data and final inventory positions. There is no direct link to the demand or the forecasted demand. In order to get the orders to cascade through the system from the customer to the Wafer Fabrication suppliers, a series of Excel based planning tools were used. The "Black Hole" refers to the fact that any wafers checked out for Wafer Sort were no longer tracked in any system.

The conversion of demand forecasts and real orders into Wafer Fabrication, Wafer Sort, Assembly and Test build requirements was completed in the Division Build Plan model. This model, however, would only calculate the Final Test requirements. The Materials Planner then calculated the remaining requests in a series of supplier models. To complete this task a large amount of data needed to be copied from the Division Build Plan model and placed in the Supplier Build Plan models. The data flow is shown in Figure 14.

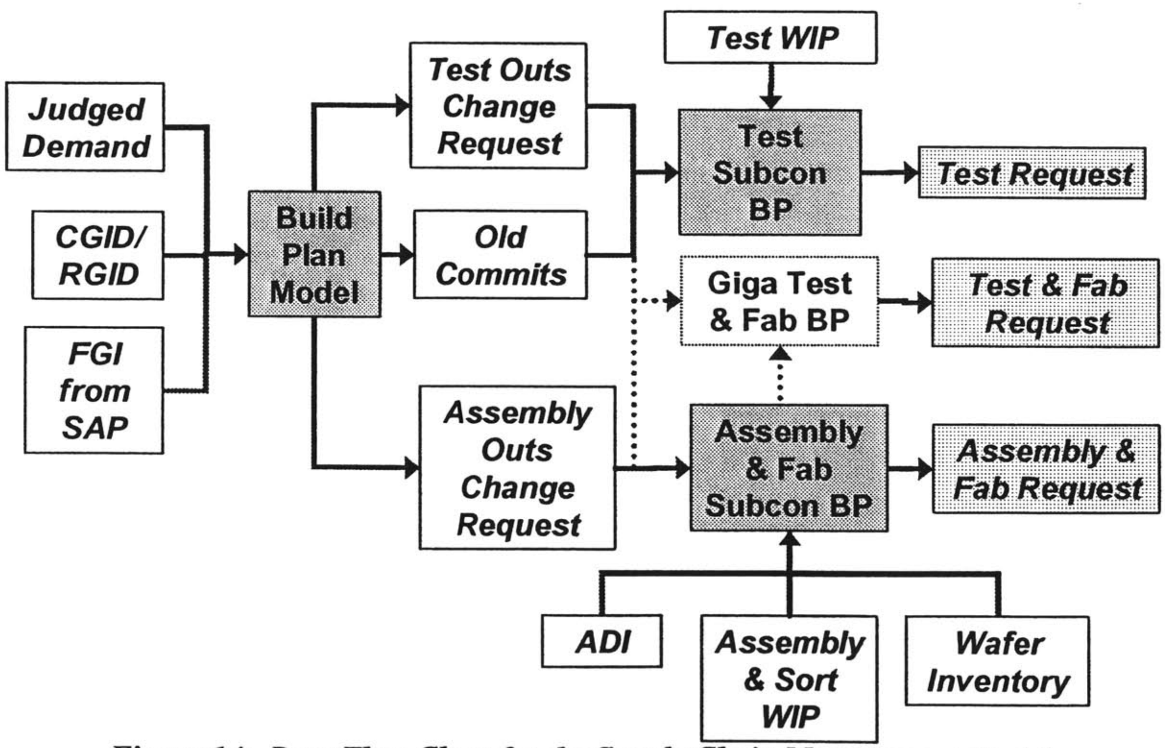


Figure 14: Data Flow Chart for the Supply Chain Management Models

Following through Figure 14 from left to right; finished goods inventory and the current orders (CGID/RGID) are extracted from SAP, Marketing's forecast, the Judged Demand, is also downloaded from a separate system and all of this data is then ported into the

Division Build Plan model. After calculating deltas between demand and inventory in the Division Build Plan model data on test needs, the old commits and assembly needs are extracted and put into several dozen models (one for each supplier). The supplier models are then loaded with inventory numbers from suppliers, Navision, and PCS. The material planner then reconciles for inventory and determines how many units need to be fabricated, sorted, assembled and tested. The supplier models then generate requests for each supplier on the quantities that must be manufactured. To understand in more detail the calculations completed in each model refer to Appendix A.

The net effect of the complexities in the system was three fold. (1) The planner and the materials manager spent fifty percent of their time tracking down data, entering data and recalculating changes with little or no confidence in the accuracy of the result. (2) Inventory counts were consistently in error. And at the end of Q2 2001 inventory was well in excess of 40 weeks, with customer lead-times of only 4 weeks. (3) It took well over two weeks to make any commits to customers upside, hurting the bottom line. A company may win orders through its ability to deliver more quickly than competitors. Delivery time reduction needs to be corporate wide, not just in the manufacturing lead time, but also in the time it take to process orders[6].

In summary Giga's Supply Chain Management system was not in good shape. Exceptions were the rule, data was inaccurate, and inventory was out of control.

1.3 Objectives

The primary objective of the work was to provide Giga scenario planning capability. This depended on the need for a robust, reliable and repeatable supply chain control system. Figure 15 outlines the general architecture and logic behind a functioning planning system. The most pressing need was for a consolidated view of the data in the enterprise. From the consolidated view, data could be passed to a control system, where decisions on builds could be made (eg, how many die to order from the foundries to

[6] T. Hill, ©1994. There are several examples cited in this text of delivery improvement through business process simplification.

support inventory targets before assembly). Or, data could be passed to a scenario planning system, where strategic decisions could be analyzed, to check for example, if inventory targets were in fact big enough to handle certain levels of upside.

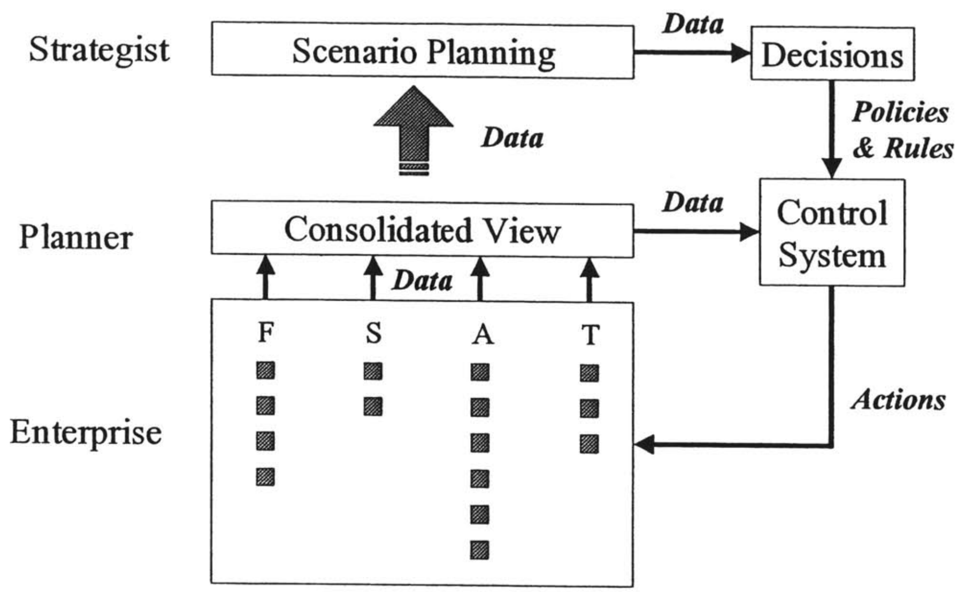


Figure 15: The Supply Chain Control System Architecture

As described in Chapter One it was found that neither the enterprise, consolidated view nor the control system was in a state that would allow for a scenario planning system. As a result of the need for a foundation for a Scenario Planning System the objectives of the work turned to the delivery of a repeatable, reliable and robust planning system.

The stated vision of the project became:

1. **Stated vision**: Clear visibility and control of our supply chain
2. **Unstated vision**: Give customers what they want, when they want it, at the lowest possible price (flexibility, delivery performance, quality & reliability, & cost).

The objective of the work to support this vision was as follows:

1. **Data**: Secure access to all data sources and identify gaps

2. **Consolidated View:** Create a single report of all supply chain data.
3. **Control System**: Implement inventory policies, rules & targets.

1.4 Approach

1.4.1 Methodology

This work will present a novel methodology used to develop and implement a Supply Chain Management system in an emerging IC manufacturing company. The details of this methodology will be discussed in more detail in Chapter Three. The approach was as follows:

1. **Develop of a Repeatable System**: Take the best of what existed and standardize it to make it repeatable.
2. **Develop a Reliable System**: Take the repeatable system and make it reliable and accurate.
3. **Develop a Quick System**: Take the reliable system and make it work quickly to shorten response time.

Based on this approach the work was divided into three phases. Phase I was referred to as the Containment Phase as the objective was to make it repeatable, Phase II the Development of Giga's Planning System as the objective was to make the system reliable, and Phase III the Development of a Build to Order System as the objective was to make the system quick and responsive.

Supporting the work and critical to the success of the project was the formation of a cross functional team. This team had representation from finance, planning, materials, manufacturing, and by the end of Phase II representation from the primary Assembly and Final Test supplier.

1.4.2 Structure of Thesis

In the remaining chapters I shall discuss the change process undertaken at Giga, the design, development and implementation of the planning system, results, discussion and conclusions.

Chapter Two will describe the development and implementation of the Supply Chain Management system at Giga. I discuss in detail the process of change, the development of the system and the restructuring of the modeling tools used to support the management of the supply chain.

Chapter Three will present results from the implementation of the new Supply Chain Management system.

Chapter Four presents a discussion on Supply Chain Management for emerging companies as well as on the design of low cost Supply Chain Management tools or MRP systems.

2 Design and Implementation of a Supply Chain Management System

2.1 The Change Process

2.1.1 Team formation

In order to support the design and development of a Supply Chain Management system for Giga it was critical to form a team. A cross-functional[7] team was assembled from most of the critical areas affected by changes in the Supply Chain Management system, namely Planning, Materials, Finance, Suppliers, Supplier Management and Manufacturing. The team was a "heavy weight"[7] team, meaning that the team had decision power and could move ahead on changes without waiting for a lengthy approval process. This allowed the team to make decisions quickly. The team membership included:

- Materials Manager
- Material Planner
- Divisional Planner
- Planning Manager
- Supplier Manager
- A/T Supplier (Phase II only)
- MIT/LFM Intern
- Operations Manager (sponsor, not core member)
- Giga Manufacturing Manager (not core member, phase I only)

To accomplish the task of building a new Supply Chain Management system in less than six months[8] required the participation of the entire planning organization. The team helped throughout the project by ensuring a high level of buy-in on the work, as all

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[7,7]. Ancona, Kochan, Scully, Van Maanen, & Westney. ©1999

[8] The LFM internship was completed from June to December 2001

members were part of the process. The team also helped to insure that the work was comprehensive, taking into account all aspects of the business. Implementation time was also reduced, as those affected by the change were already part of the development process, requiring no additional education or buy-in.

2.1.2 The 3-Phase Process

A three-phase process guided the development and implementation of the Supply Chain Management system. This three-phase process was based on the principle that without first establishing a baseline no future improvements could be made with certainty. This process would follow the three basic steps:

I. **Develop of a Repeatable System**: Take the best of what existed and standardize it to be repeatable, whether or not it was the best way.

II. **Develop a Reliable and Accurate System**: Take the repeatable system and make it reliable and accurate.

III. **Develop a System for Low Cost & Speed**: Take the reliable system and make it work quickly to shorten response time, and at the lowest cost with minimum overhead (inventory and people).

Most methodologies used for reengineering systems and business process revolves around the Plan-Do-Check-Act (PDCA) approach pioneered by W. Edward Deming[9]. PCDA is most useful in the context of continuous improvement but does not provide a framework for the scope of each cycle. One approach to developing a solution for Giga may have been to develop a complete solution from the start and then attempt to implement it. The approach used in this work focused, instead, on first bringing the business processes into control before developing or implementing a solution. The three-phase methodology most closely matches the Capability Maturity Model[10] used in helping software organizations improve the maturity of their software processes. This methodology rates and organizations maturity as follows:

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[9] Deming, ©1986

[10] Paulk, M. ©1993, pp. 18-27

1. **Initial**. The software process is characterized as ad hoc, and occasionally even chaotic. Few processes are defined, and success depends on individual effort and heroics.
2. **Repeatable**. Basic project management processes are established to track cost, schedule, and functionality. The necessary process discipline is in place to repeat earlier successes on projects with similar applications.
3. **Defined**. The software process for both management and engineering activities is documented, standardized, and integrated into a standard software process for the organization. All projects use an approved, tailored version of the organization's standard software process for developing and maintaining software.
4. **Managed**. Detailed measures of the software process and product quality are collected. Both the software process and products are quantitatively understood and controlled.
5. **Optimizing**. Continuous process improvement is enabled by quantitative feedback from the process and from piloting innovative ideas and technologies.

The first phase describes the movement of the organization from Initial to Defined. The second phase from Defined to Managed and the third phase from Managed to Optimizing.

To guide the team through each phase in the project a new vision and set of deliverable were created. Although the deliverables did not map exactly to the overall three-phase structure initially proposed the basic idea of the three phases were maintained. The new vision and deliverable helped to clarify the transition between phases. They also allowed for a higher degree of focus by the team. Automation, sophisticated planning and build to order were not immediate goals, allowing focus to be maintained each step of the way.

Phase	Vision	Deliverables
I: Containment	Gain Control of the System	• Improve Quality by Reducing Errors. • Improve Flexibility by shortening BP cycle • Improve Delivery through better inventory management • No bells and whistles – just what we need to get the job done. • Standardize how we execute orders and manage inventory • Simplify our modeling tools • Clean up Navision and PCS
II: Development of Giga's Planning System	Design a Solution for Giga	• Improve Flexibility with strategic inventory positioning • Consolidate inventory data • Improve Quality with a more robust MRP system • Improve Delivery with accurate lead time estimates • Eliminate PCS • Shorten Lead time
III: Develop a Build To Order System	Make the supply chain a competitive advantage	• Enable Build to Order • Enable instant confirmation of upside • Develop a single Build Plan • Move to an off the shelf MRP system • Enable a self managing system (auto calculations)

This approach allowed for a systematic improvement of the Supply Chain Management system. Each phase would be fully completed and implemented before moving on to the next. As a result, real, tangible results were possible. Had the ideal system been fully designed from the start it is very possible none of the ideas would have been implemented. The formation of the team and use of the three phases has also built an organization in the logistics department that is focused on continuous improvement. Small steps, in this case, have led to the development of a sophisticated system, with little cost and over the course of only six months.

2.2 *Business Process Standardization*

2.2.1 Business Process Mapping

This work demonstrates a practical use of business process mapping as a methodology for analyzing problems and creating change in an organizations. Key to discovering the problems at Giga and in formulating solutions was the mapping of the business process and systems used. In Chapter One the process of handling orders through the supply chain was described in detail using event flow mapping, as an example.

At the start of the project the process mapping of the supply chain processes utilized a holistic approach, showing in a single map all transactions in the management of material through the supply chain. To help in the reading of the map each event type was assigned a unique shape. In addition the location in the supply chain that the event took place was marked with a factory symbol and the name of the location, such as Fab or Assembly.

The event flows shown in Chapter One were created from data collected during interviews of each member of the planning organization. Each team member had a different piece of the story to tell, as they had been traditionally responsible for separate suppliers. No single member of the planning organization knew the complete process. Once mapped the flow chart was presented to the team and reworked several times producing the final event map.

Once the map was created it was instrumental in conveying to the organization the need to simplify and find a better process to follow. This final process too was mapped and is shown later in this chapter. This event map was then converted to a sequence of steps and applied to a Gantt chart to help standardize the timing and ownership of each event. This Gantt is also shown later in the Chapter.

As the project progressed the necessity of a holistic view of the system changed to a need to look at the details. By the end of Phase II the details of the business processes were more critical. At this time a new method of process mapping was utilized. In this case the maps were limited to a single business process and were people rather than process centric. A good example of this is the process of creating wafer orders and is shown in the Figure 16.

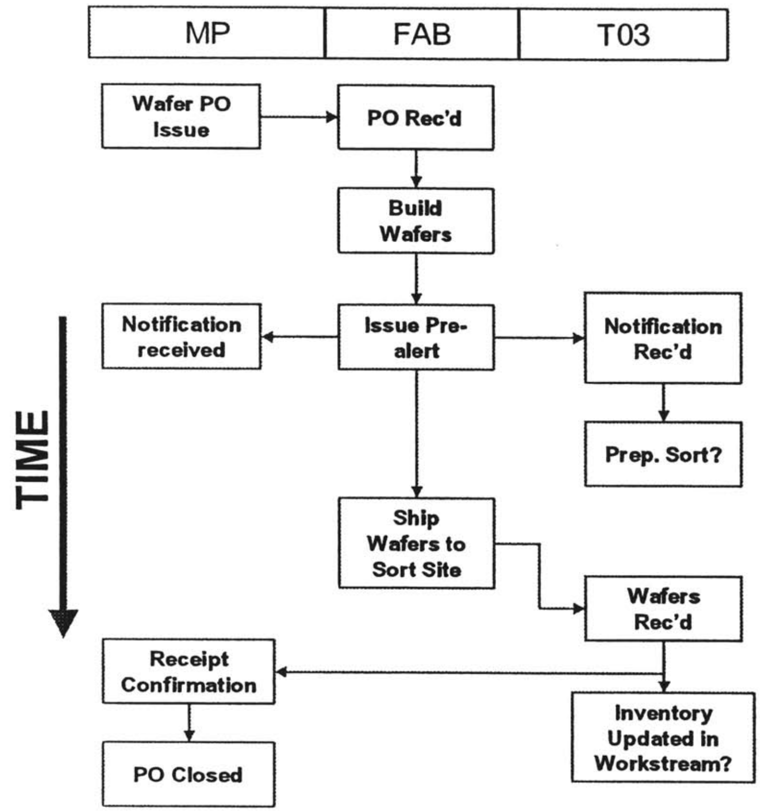


Figure 16: Example Business Process Map

The process shown in Figure 16 had been represented by only two events in the event map from Chapter One. This approach also emphasizes the ownership and timing or sequence of each event. The migration from a whole systems view of major events to a detailed process flow of the business activities was key to developing solutions that would be effective in the system at large.

2.3 Phase I

2.3.1 Phase I Process Standardization

The first phase of the project focused on containment; building a repeatable system. Using the event flow mapping of the entire supply chain, the team focused on developing a standard process. With the objective of having a single approach for managing orders the team chose the supplier relationship that worked the best. All of the interactions were copied exactly to ensure standardization. The objective of Phase I was to make a repeatable system, not necessarily an optimal one. The primary changes were as follows:

- A Sort PO was created to track quantities in Navision.
- A Sort Tracking Sheet was created to keep count of die in Giga's sort facility.
- A PO was cut for all assembly suppliers, including Giga.
- Suppliers were required to send pre-alerts to the MP for all die moving to test.
- A test PO was cut for all suppliers, including Giga.
- One PO was cut for each supplier each month for four weeks of demand (amended Purchase Orders would be cut for changes). A monthly PO would be cut instead of having one cut for every batch or single order.
- Inventory was issued to the assembly suppliers to support the four weeks of demand plus four additional weeks of forecasted demand. This minimized shipping and allowed upside at the assembly sites.
- The MRP modeling tools were simplified and data links between the inventory and the Division Build Plan model and the Supplier Build Plan models were created.

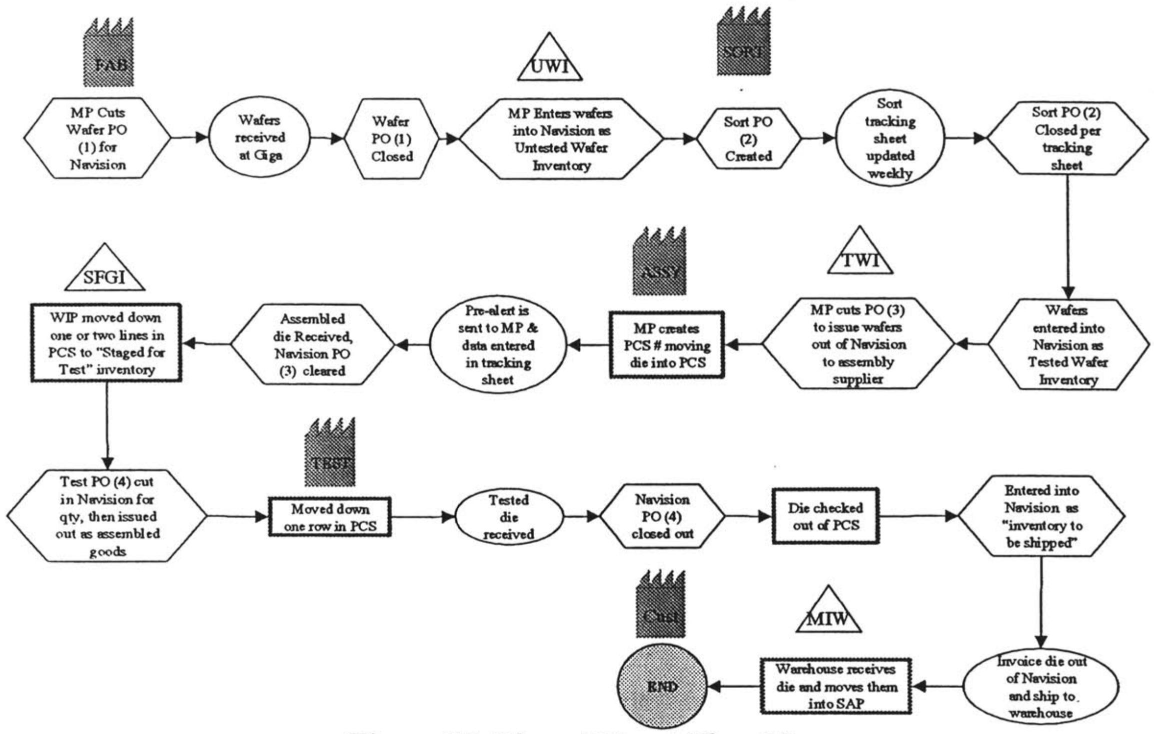
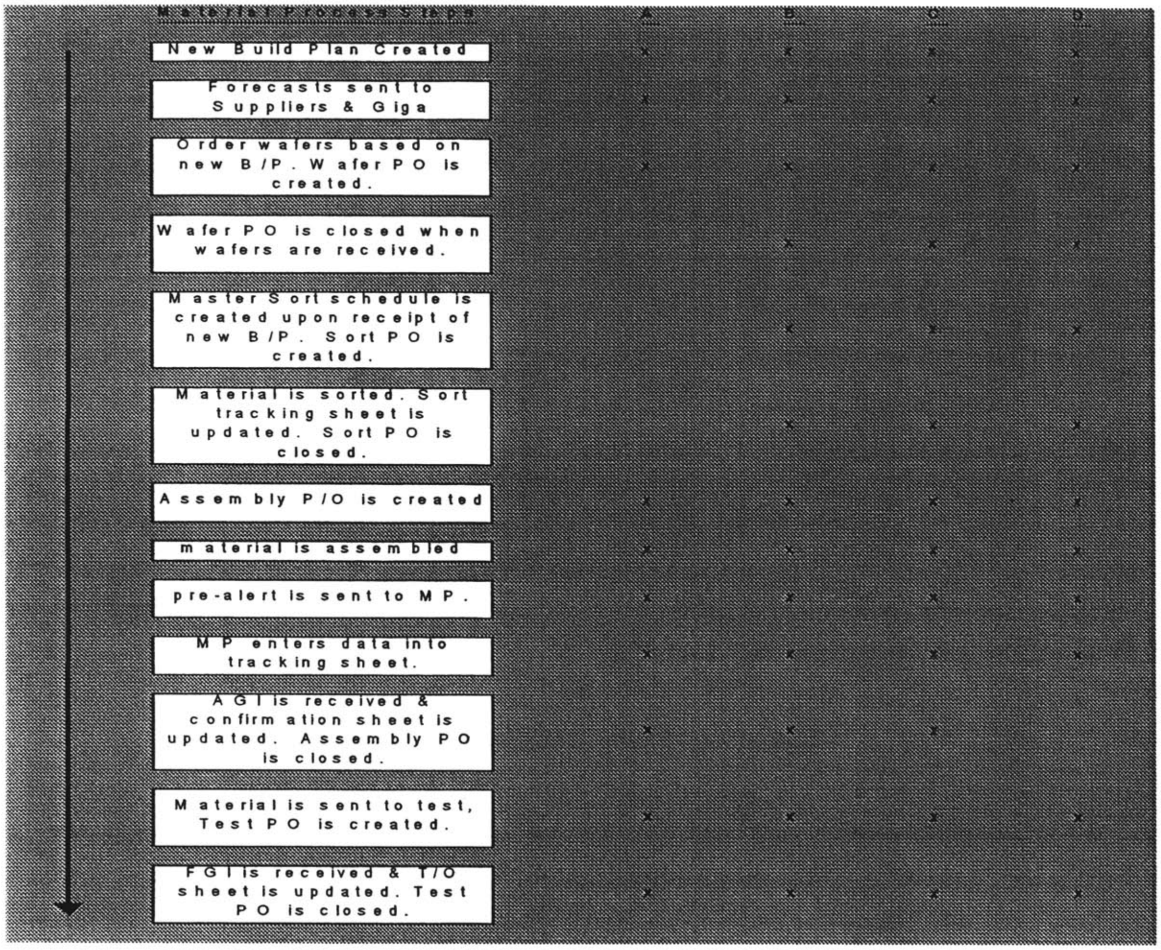


Figure 17: Phase I Event Flow Map

Figure 17 shows the event flow for Phase I. From the flow map we see the standardization now planned for Phase I. All exceptions were removed from the process. Regardless of where the materials were to be shipped the same transactions were executed. Besides making the work easier for the materials planner it also allow the entire inventory to be tracked in some fashion, whether in Navision or in a tracking sheet.

The next step in the process of standardization was to develop a business process. To accomplish this task the team worked through each major activity involved in creating orders to send to suppliers. In addition we mapped which suppliers at that time actually used each process to find commonality. The objective here was to find the best standard to apply to all suppliers. The mapping and process flow is shown next.



Type	Sort	Assembly	Test	F/G
A	Supplier 1	Supplier 1	T3	T3
B	Giga	Supplier 2	Giga	Giga
C	Giga	Supplier 2	Supplier 2	Giga
D	Giga	Giga	Giga	Giga

Figure 18: Business Process and Mapping to Suppliers

Using the event map with Figure 18 and assigning timing and ownership, a Gantt chart outlining the events was created. This Gantt chart then became the standard process used by the planning organization for Phase I. It also revealed to the team the total amount of time allocated to turning a forecast into orders. This time was set to be just about three weeks. This was close to the estimated turn time of one month and was thought to be lower due to the optimistic estimates of each event.

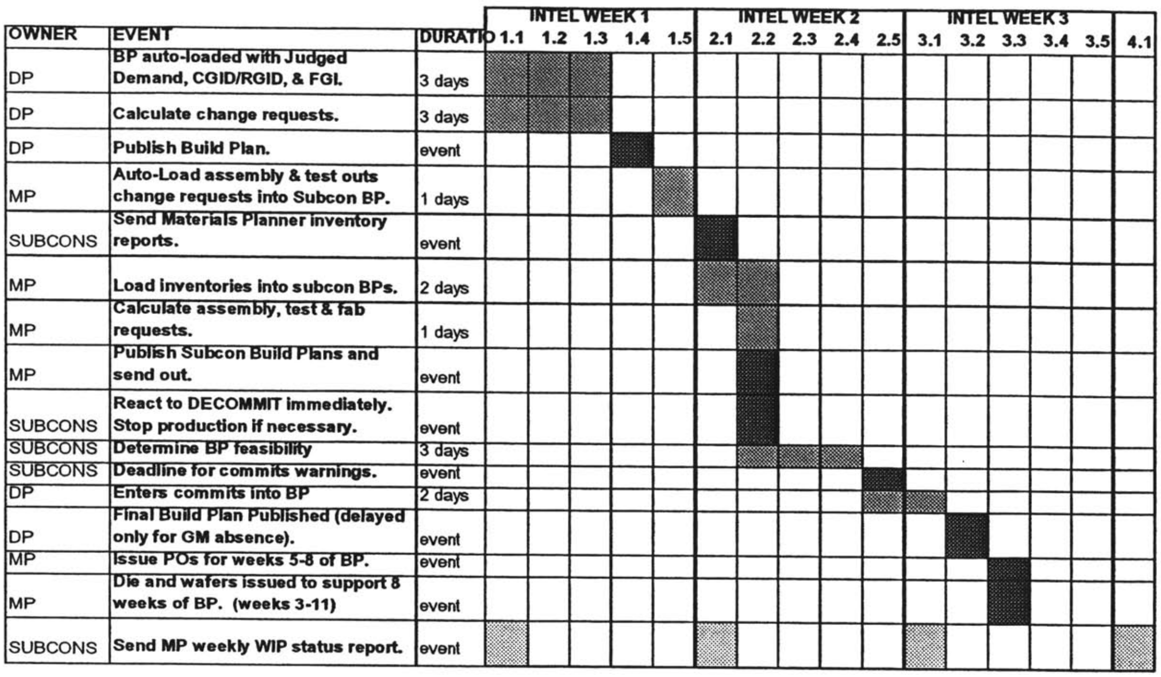


Figure 19: Phase I Business Process Gantt

With a repeatable business process the core of Phase I was completed. The only remaining work was to standardize the modeling tools used to generate the orders.

2.3.2 Separation of New Products from High Volume

New Product Introductions or NPI is a necessary core competency of a high tech company like Giga. To increase the Giga's focus on NPI and to simplify the planning process of high volume products the two were separated. NPI would no longer be managed in the Division Build Plan model.

Previously, all products, whether in the development phase or already for sale in volume were included in the Build Plan models. A separate NPI model was created, which could be used to track the products movement through the supply chain on a batch-by-batch basis. In addition an NPI planner position was created to manage this process. Subsequently all of the NPI products were removed from the Division Build Plan model. These products represented about 10% of the total number of line items. They were left, however, in the Supplier Build Plan models, as the material planner would continue to be the sole contact for creating build request.

2.3.3 Phase I Build Plan Model Simplification

The Build Plan models were a key element to the management of the supply chain. They were the only connection between customer orders and the inventory and generated all supplier requests to manufacturing product. As described in the first chapter, data was loaded into the Division Build Plan model from SAP along with forecasted demand and finished goods inventory.

At the start of the project there was a limited amount of data automation to move data into the model. In addition, the model's size was well over 40 megabytes. To simplify the use of the model, code was written which automated the downloading of all of the needed data; the finished goods inventory, customer orders and forecasted demand. In addition changes were made to the formulas in order to reduce the amount of errors and subsequently the size of the model. The model was reduced to less than 12 megabytes.

The next step in the simplification process was to connect the Supplier Build Plan models to the Division Build Plan. This was accomplished by writing code that extracted the Final Test requirements from the Division Build Plan and placed them into each of the Supplier Build Plan files. This reduced the data population time from three days to less than five minutes, freeing up more time for the Material Planner and reducing the time it took to respond to customer upside requests and new demand forecasts.

The final step in creating a better modeling system for Phase I was the standardization of the output. Previously each Supplier Build Plan was slightly different. The differences were due to the fact that each supplier expected a different format for their forecast and a different build horizon. Some were only issued POs for a week's worth of work and inventory to support it while others received four weeks.

To standardize the Supplier Build Plan models one format was chosen and then replicated for each supplier. In addition new features were added to consolidate the inventory and calculate shipping requirements. The old models were then discarded. This standardization was also key in allowing the data movements from the Division Build

Plan model to be automated, as the destination of the data was now identical, regardless of the Supplier Build Plan model. The models each would contain a section for every product sent to that particular supplier. Figure 20 shows an excerpt from one of the Supplier Build Plan models. The model shows the 'demand'[11], the 'Supply', what the supplier was committing to and the delta. The model also provides the current inventory position, and based on forecasted demand over the next eight weeks, how many wafers to send to support the build.

Giga Materials Planning

Supply X Supply & Demand Forecast

Build Plan Cycle: **Oct'01**

Component	Wafer ID	Location		Component BOH	WW36	WW37	WW38
Product XYZ	III	Penang	Demand		1	1	1
			Supply	957	1	1	1
			Delta	957	957	0	0
	To Ship	-7	Cum Delta		957	957	957
Product XXY	IVI	Penang	Demand		0	0	0
			Supply	347	0	0	0
			Delta	347	347	0	0
	To Ship	0	Cum Delta		347	347	347

Figure 20: Requirements Calculation from the Supplier Build Plan

A major addition to the Supplier Build Plan models was inventory sheets. Rather than have inventory added as a single data point for every product, a consolidated sheet was created. The idea was to simplify the data entry process and provide an easy to see data sheet. It also provided information on where the material was in the supply chain. Instead of having a single inventory total on the product sheet the model now had the inventory broken up by site before being totaled.

[11] 'Demand' was extracted from the Divisional Build Plan model and had already been adjusted for finished goods inventory

BOH Wafer Inventory		Wafer				
Wafer ID	DPW	ADI	Sorted	Supplier X Die Bank	Supplier Y Die Bank	Total
Wafer Type 1	800	4		4	10	18
Wafer Type 2	900	5		5	10	20
Wafer Type 3	. 1,000	1		1	10	12
Wafer Type 4	9,000	2		2	10	14
Wafer Type 5	1,000	6		6	10	22

BOH Die Inventory		Assembly			
Product	Wafer ID	WIP	SFGI	at Test	Total
Component XYZ	Wafer Type 1	957			957
Component IVI	Wafer Type 2	347			347
Component SDY	Wafer Type 3	478			478
Component SDF	Wafer Type 1	960			960

Figure 21: The Supplier Build Plan Inventory Sheet

Finally a standardized build request sheet was created. The build request sheet, used to summarize orders, is sent to each supplier. This sheet, like all sheets in the model, was identical regardless of the supplier. All parties involved agreed upon the format. It was in fact considered an improvement by many suppliers as they wanted to see the longer term forecast and have access to inventory earlier to help optimize their build schedules. An example of this sheet is shown in Figure 22.

Giga Materials Planning

Supplier X Demand Forecast

Date: **July 30, 2001**

By Week Forecast:

Giga Component	Wafer ID	WW36	WW37	WW38	WW39	WW40	WW41	WW42	WW43
Component XYI	Wafer Type I	-	-	-	-	-	-	-	-
Component SFD	Wafer Type I	-	-	-	-	-	-	-	-
Component YTI	Wafer Type I	-	-	-	-	-	-	-	-
Component ETK	S1862A1	-	-	-	-	-	-	-	-

By Month Forecast:

Giga Component	Wafer ID	SEP-01	OCT-01	NOV-01	DEC-01	JAN-02	FEB-02	MAR-02	APR-02
Component XYI	Wafer Type I	-	-	-	-	-	-	-	-
Component SFD	Wafer Type I	-	-	-	-	-	-	-	-
Component YTI	Wafer Type I	-	-	-	-	-	-	-	-
Component ETK	S1862A1	-	-	-	-	-	-	-	-

Figure 22: The Supplier Build Plan Request to Build Sheet

2.3.4 Walk the Flow

The end of Phase I was marked by a "walk-the-flow" exercise. This exercise involved stepping through each task that was required to meet each business process. In addition the calculations in the Division Build Plan model were reviewed, as was the proposed Phase I Gantt chart. Following ratification of the process Phase I was put into practice.

2.4 Phase II

2.4.1 Phase II Process Improvement

The objective of Phase II was to build on the repeatable system implemented in Phase I, making it more reliable. Using business flow mapping and the foundation provided by Phase I, the team was now in a position to create a more robust and responsive system. Cycle time goals were set to drive these changes.

METRIC	DESCRIPTION	GOAL	STRETCH GOAL
Business Process Cycle Time	The time it takes to convert a request to a commit.	3 working days	Zero (build to order)
Assembly/Test Cycle Time	The time it take to deliver units from the die bank to warehouse	Two weeks	One week
LIPAS	Line Item Performance to Schedule. Orders fulfilled on time divided by orders requested	100%	100%
VOLPAS	Volume performance to schedule. Volume produced divide by volume required	100%	100%

To meet these targets and make the system more robust, the following changes were made:

- The PCS System was put off line
- Inventory targets and locations were chosen
- A push-pull[12] system was implemented
- Unsorted wafers were sorted and moved to die inventory
- The Supplier Build Plan models were consolidated

[12] Push/pull refers to the combination of a build to orders system for the front-end process and a build to order system for the back-end process. Simchi-Levi, ©2000

- Assembly and Test suppliers were consolidated

2.4.2 T03 & Supplier Consolidation

In parallel to the work on building a standardized supplier management system the supplier base was streamlined. At the start of the project there were about four sort sites, six assembly, and three test sites. To simplify the supplier base Giga decided to select a single sort, assembly and test site with occasional support provided by Giga manufacturing. T03, Intel's main test site in Penang Malaysia was selected through a competitive bid process.

Selected members of T03's planning organization were asked to join the Supply Chain Management team. The transition to T03 would not be instantaneous, but would occur over the course of one year. In addition, only high volume products would be produced by T03. This change would allow the NPI products to be completely phased out of the Supplier Build Plan models. Giga would become the sole manufacturer of NPI. Giga would in turn no longer handle any high volume. This transition too would occur over the course of one year. In this new environment there would be a clear division between high volume and NPI.

Giga manufacturing would be separated with their own planner managing NPI and their build schedules. With the planning requirements of NPI and high volume being very different this separation would allow better focus on the right issues allowing NPI to get the attention it demanded. The separation would also allow the high volume-planning overhead to be reduced.

2.4.3 Business Process Focus

In Phase I the primary focus was on the standardization of the Build Plan Reset process. This process was the core business cycle that the planning department followed on a monthly basis. With this process standardized and repeated every month the team began to focus on finding exceptions. This research uncovered the other two primary business processes that were occurring. These processes were described in the first chapter and are (1) demand rationalization and (2) customer order changes. Demand rationalization was occurring each week to ensure that orders on the books matched orders in SAP. Customer order changes occurred at random.

The first exercise was to map out these business processes to establish both the sequence of events and the roles and responsibilities. This process had a major impact on the project. First of all it introduced additional members of the planning process. They were the Customer Business Analyst (CBA) and the Business Process Analyst (BPA). The CBA was the direct contact for the customer. The BPA was the connection between the CBA and Giga. These relationships are detailed in Figure 25. The BPA was also responsible for maintaining data in SAP. We were also able to map directly to the customer. The other impact was to demonstrate to the team the dependencies of each step and the overlap each process had on one another, as shown in Figure 23. Finally it was helpful in demonstrating the repetition of much of the work, highlighting opportunities for improvement.

In an effort to improve the reliability of the system it was the team's objective to incorporate the use of the standard Division Build Plan model for all cycles. Previously, changes in customer orders were handled off line, without interrupting the Build Plan Reset process, but often confusing the final demand values. This was also the case with the demand rationalization. It was therefore established that the Build Plan Reset process and model would need to be easy enough to use that it could support these 'off-cycle' changes.

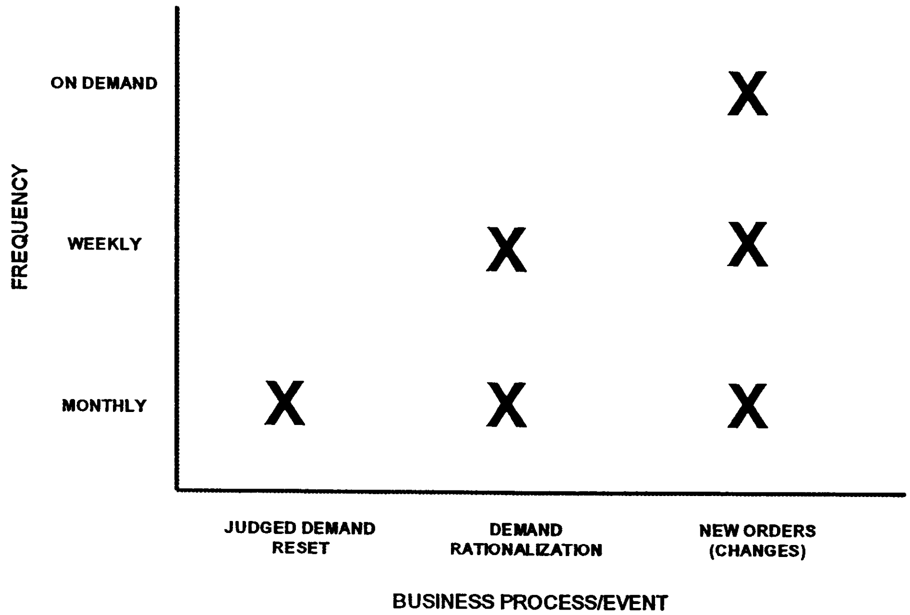


Figure 23: Business Process Overlap Matrix

The first business process mapped was the standard Build Plan Reset process. The mapping reflected exactly what the Gantt chart developed in Phase I described. With this as our baseline model the other two processes were mapped. The product of this work is shown in Figure 24. The process follows closely with the Build Plan Reset with decisions made by the CBA instead of the Giga staff[13]. As this process was executed weekly it was decided to overlap it with the Build Plan Reset. However, as it dealt only with backlog or confirmed orders, the results could be sent out to each supplier prior to the Division Build Plan approval. Approval was only needed on forecasted demand.

[13] Giga Staff is referred to as the OCE Staff in Figure 24

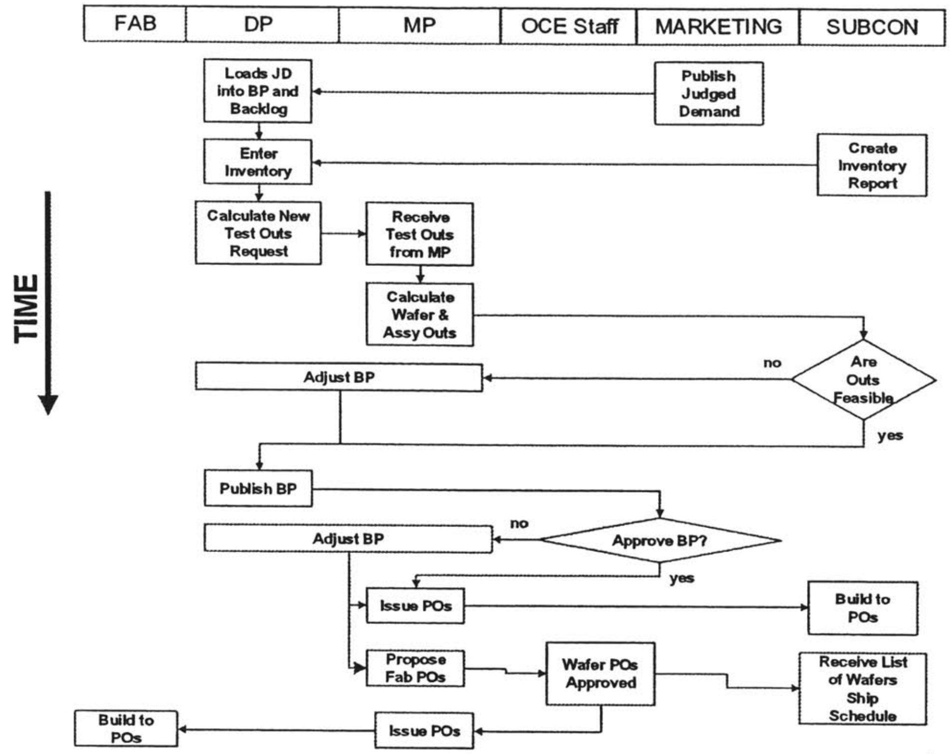


Figure 24: The Build Plan Reset Process

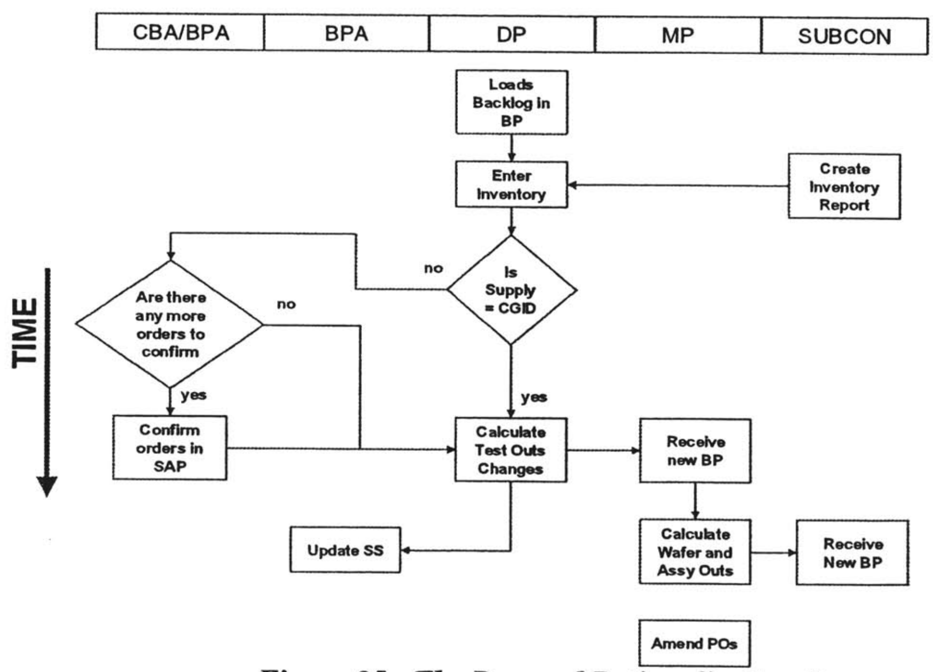


Figure 25: The Demand Rationalization Process

The next process studied was the Customer Change Request process. This was determined to be the most critical as it dealt directly with customer service. While it was important to turn around the Build Plan Reset quickly to minimize supplier over builds, it was even more critical to meet customer upside requests in a timely fashion. The response time was measured from the customer's change request to the customer's receipt of the new commit. No baseline had been established but it had been estimated that this time was in excess of one week[14]. For Phase II this target was set to three days.

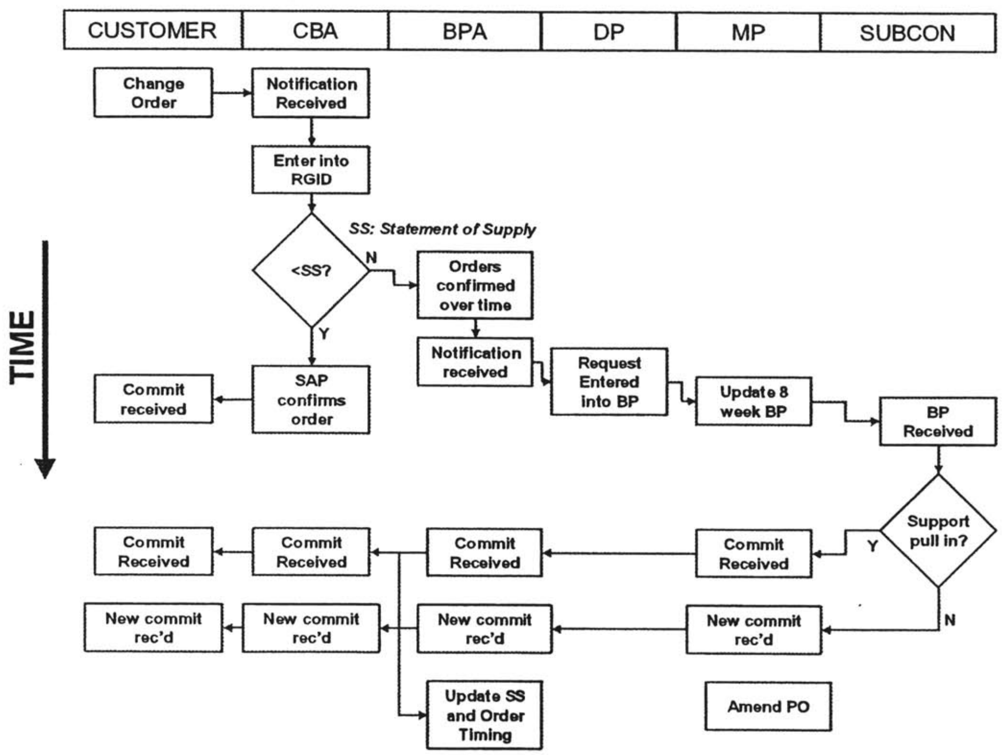


Figure 26: The Customer Change Request Process

It was also made apparent through the analysis that several of the communication activities were repeated. For example the commits sent out by the suppliers were passed first to the MP, then the BPA, then the CBA and finally the customer. Due to the existing

[14] The turn around time was only for cases where the supply shown in SAP was less than the request as shown in Figure 26.

relationships no changes were made to this process. It did however give the team an idea of possible future improvement opportunities.

To improve the system, the team focused on activities that required the most amount of time. It was important to both decrease the cycle but also establish standard business practices to increase the reliability of the system. These two goals were at times in conflict. To ask the planners to enter each change request into the Division Build Plan model and then pass on the data to the Materials Planner before issuing an upside request to the supplier seemed like an unnecessarily complex route. The previous procedure, if there was one, was to pass on individual requests via email to the materials planner. The problem with this was the emergence of several open requests, some of which were in the model, some of which could still be in an email. The solution was again to simplify and improve the tools used for the communication so data entry and data sharing would not be an issue. The final process used was put into a Gantt chart shown in Figure 27.

CGID/RGID CHANGE PROCESS								
			INTEL WEEK 1					
OWNER	EVENT	DURATION	x.1	x.2	x.3	x.4	x.5	
DP	BP auto-loaded with CGID/RGID, & FGI.	event						
DP	BP auto-load FGI	1/2 days						* HOW DO WE KEEP FGI UP TO DATE IN BP?
DP	Calculate change requests.	1/2 days						
DP	Calculate Test Out WAS/IS	1/2 days						
DP	Publish T03 Build Plan and send out.	event						
T03	React to DECOMMIT immediately. Stop production if necessary.	event						
T03	Determine BP feasibility	2 days						
T04	Deadline for commits warnings.	event						
DP	Enters confirmed commits into BP	1/2 days						
?	Confirmed Statement of Supply entered into SAP	event						* WHO DOES THIS?
?	Issue POs for weeks 5-8 of BP.	event						* WHO DOES THIS?

Figure 27: Phase II Customer Upside Request Business Process

2.4.4 The Push Pull System

The process of manufacturing integrated circuits can be divided into two major parts, the fabrication and sorting of the wafers and the packaging and testing of the die. This division is characterized by two key attributes, cost and cycle time. The fabrication of die on wafers and the sorting of wafers and assembly and testing of the die each represent

50% of the total cost. The lead times of Wafer Fabrication can take anywhere from ten to sixteen weeks, while Assembly and Test can be accomplish in one to four weeks.

These differences lead to the development of a Supply Chain Management system that combines both a Push and a Pull system. In a Push supply chain, production and distribution decisions are based on long-term forecasts. Push systems arise when the lead-time to manufacture a product is greater than the lead-time expected by customers. A Push system requires that inventory is built without confirmed orders. In a Pull supply chain production and distribution are demand driven so that they are coordinated with true customer demand rather than forecast. That is, in a pure Pull system, the firm does not hold any inventory and only produces to order[15].

In the case of Giga's manufacturing there existed a need for a combination of a push and pull system. Typical lead times expected by customers were around two to four weeks. As a result die would need to be ordered based on a forecast but die could be assembled and delivered on demand. In Phase I however, it was common to find assembly and test lead-time in excess of five weeks. As a result Giga held finished goods. However, with the consolidation of assembly and test to a single supplier and the reduction in the time to turn around commits Giga was in a position to build to order. The wafer ordering process would be driven as always by forecast.

The interface between the push-based stage and the pull-based stage in the supply chain is referred to as the push-pull boundary[9]. In the case of Giga, this boundary would be set just after the sort operation but before the assembly step. The advantages of this strategy are as follows:

- Finished goods inventory could be eliminated, saving on holding costs
- Giga could manage the Push system; ordering wafers to forecast while T03 could manage the Pull system, assembling and testing die to order (from SAP). This

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[15] Simchi-Levi, ©2000

would reduce the time needed to meet upside requests, as the customer would be interfacing with the factory more directly. In addition it would reduce the overall burden by removing Giga from the decision loop.

- Inventory would be in one location only, reducing exposure and simplifying the tracking process.
- With a single wafer type capable of servicing multiple products die inventory would be more flexible in the face of mix changes than finished goods.

The supply chain for Giga is shown in Figure 28. Wafer Sort would receive die from the Wafer Fabrication suppliers and sort them on arrival. Assembly would be issued die from the Sorted Die Inventory based on test requirements. Test would issue build requirements to Assembly based on confirmed orders. These confirmed orders, however, would first need to be approved by Giga through the standard Build Plan Reset process due to the fact that several of the customers were experiencing financial constraints and were on credit holds. In addition, any upside requests entered into SAP would have to be worked through the process due to the lack of accurate capacity information. As such, T03 could not act independently as was hoped.

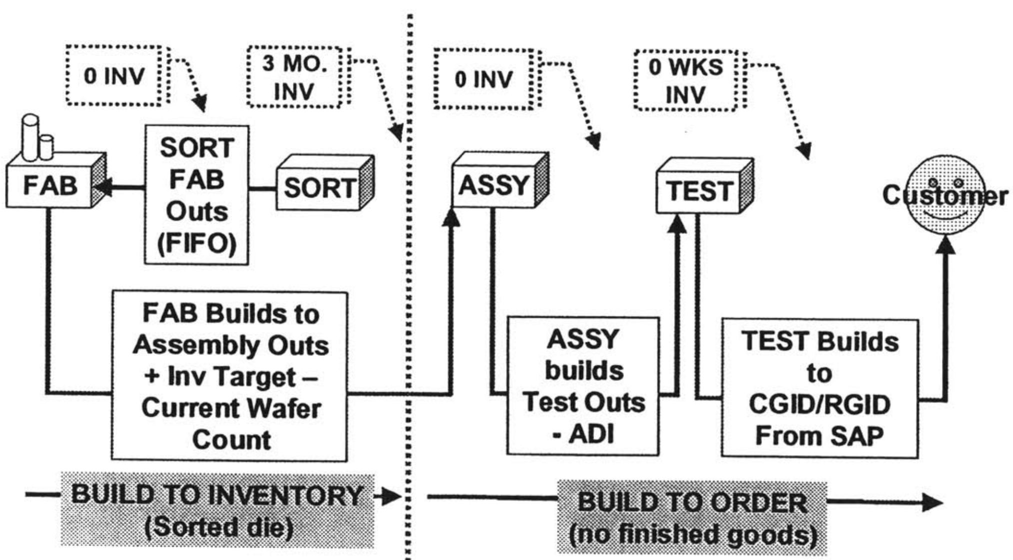


Figure 28: Giga's Supply Chain Inventory Strategy, the Push-Pull System

2.4.5 Model Simplification

The major focus in model simplification for Phase II was in the consolidation of the Supplier Build Plan models. This consolidation would accomplish two things. First, it would allow all inventory to be tracked in a single location. This was extremely valuable for products that were manufactured by two separate suppliers. With the same product tracked in two separate models the probability of error was increased. Second, it would reduce the overhead needed to manage several different models. The reduction in overhead would relieve the MP from much of the work allowing more focus to be paid to the NPI transition and customer upside requests.

The resulting inventory sheets now represented the entire supply chain. This enabled a grand total of units to be easily calculated and used to drive wafer orders more accurately. Wafer purchases represented over 50% of the total cost of sales; the accuracy of the orders was critical. With a single wafer type capable of being used for several component types having all of the components in one file eliminated any errors due to incorrect division of inventory.

Giga Materials Planning

BOH Inventory

Date: **November 28, 2001**

BOH Wafer Inventory		**Wafer**		**DIE BANKS**								
Wafer ID	DPW	ADI	Sorted	FR	HK	Penang	Giga	US	UK	Korea	Philippines	**Total**
Wafer Type 1	1,400	4								4	10	18
Wafer Type 2	1,500	5								5	10	20
Wafer Type 3	1,400	1								1	10	12
Wafer Type 4	1,500	2								2	10	14
Wafer Type 5	700	6		3						6	10	25

BOH Die Inventory		**Assembly**										
Product	Wafer ID	FR	HK	Penang	Giga	US	UK	Korea	Philippines	SFGI	at Test	**Total**
Product XIS	Wafer Type 1							957				957
Product SDF	Wafer Type 2							347				347
Product SGO	Wafer Type 3							478				478
Product XYZ	Wafer Type 1							960				960
Product XXX	Wafer Type 2							348				348
Product YYY	Wafer Type 3							479				479

Figure 29: Phase II Inventory Tracking Sheet.

The inclusion of complete component data allowed the wafer-ordering model to be added to the Build Plan Model. The wafer-ordering sheet would calculate when to purchase lots (batch of die) based on forecast, inventory and inventory targets. This model is shown in the Figure 30.

Giga Materials Planning
Wafer Supply & Demand Forecast
Date: **September 4, 2001**

Giga Component	Wafer ID	Wafer Supplier	Data			Component BOH	WW36	WW37	WW38	WW39
Component SGY	Wafer Type 1		Yield	1	Demand		3	1	1	1
Component SDH			Die Per Wafer	1300	Inventory	0.0	0.0	0.0	1.0	1.0
			Weeks Delivery	1	Dock		0	1	0	0
			Target	0	Delta		0.0	1.0	1.0	1.0
			DIE INVENTORY	0	Order		1			
Product XYZ	Wafer Type 2		Yield	1	Demand		0	0	0	0
Product XXX			Die Per Wafer	1300	Inventory	0.0	0.0	0.0	1.0	1.0
			Weeks Delivery	1	Dock		0	1	0	0
			Target	0	Delta		0.0	1.0	1.0	1.0
			DIE INVENTORY	0	Order		1			

Figure 30: Wafer Build Plan for Phase II

2.5 Phase III

2.6 The Future State

At the time of this work, the move to Phase III was still under way. The work completed represents the start of the development but not the implementation. The objectives of Phase III were to build an intelligent supply chain that was self-managing, the ultimate goal being to provide a build to order system. In other words, orders placed would automatically generate requests throughout the supply chain based on inventory targets provided by the planning organization. In addition, orders placed would be built with no finished goods inventory target. The job of the planners would be to execute the process of data population and then distribute and maintain appropriate inventory targets and oversee the process as a whole. This task could theoretically be completed in a few hours.

2.6.1 Build to Order & The Need for Capacity

One of the major limitations of the system in place was the time and effort required to confirm upside requests from customers. Ideally, one would like to be able to immediately confirm an order or propose a firm delivery schedule. Instead, customers are required to wait up to three days for a reply. Obviously this is not an ideal customer service model. It should be noted that short-term upsides were rare and only needed when near term forecasts were inaccurate. Any upside seen outside of four weeks could be met without question. The need for analysis was only for orders increased within the lead-time of assembly and test.

Despite the rarity of short-term upside requests it was still the goal of the team to provide zero turn time. The missing link is the suppliers' true upside capability or capacity. Typically, the supplier will reserve capacity based on the forecast and will do this for several customers. If there is enough demand in the system for all customers then short-term upside is impossible. Knowing this is a critical piece of information.

Several solutions are being pursued. First is to connect the Build Plan model system to the supplier's capacity model. This approach is seen as very complex and prone to error. The second approach is to pre-purchase capacity upside based on the variability of the demand. Given certain demand variability and a promised service level a percent upside can be determined. And the third option is to hold finished goods inventory. While the promised lead-time of Assembly and Final Test is one to two weeks, when filled to capacity this lead-time is extended. The result is to carry inventory to cover the difference between promised lead-time and customer's expected lead-time.

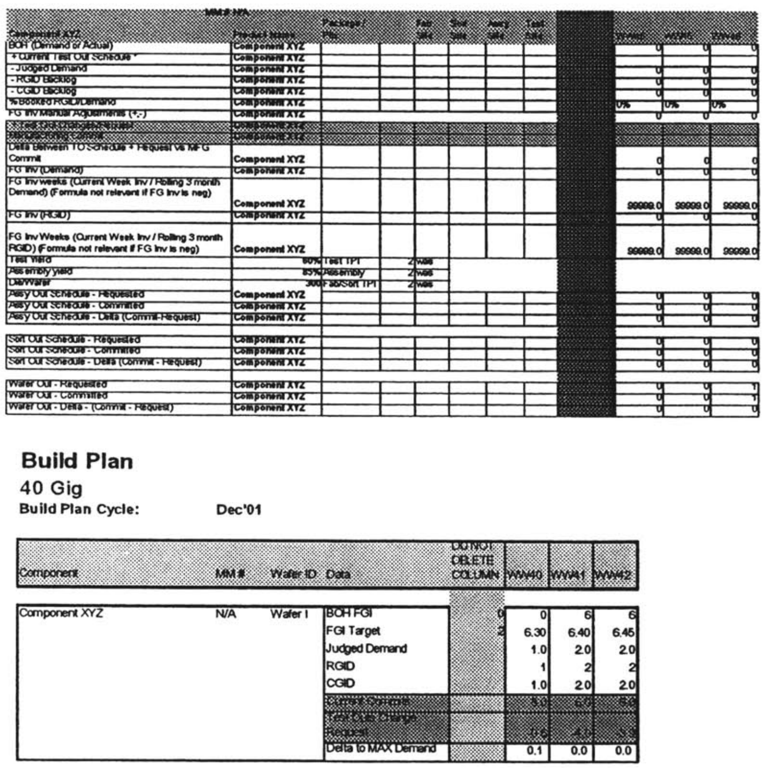
2.6.2 The Phase III Build Plan Model

Model simplification for Phase III focused on the final consolidation of all of the Build Plan models and the addition of algorithms that would calculate build requirements based on demand and inventory targets. With a single standardized Supplier Build Plan model it was logical to then combine it with the Division Build Plan model, thereby reducing the need to port data and perhaps consolidate the role of planning to a single person.

2.6.2.1 Model Simplification

Prior to the combination of the models, the Division Build Plan model was again simplified. The focus was on reducing the number of elements needed to produce a resulting demand request for each product. The management of the data would also be changed. The model held data, such as inventory, as a single line in each product section. The result was the dilution of the data throughout the model, increasing the errors and creating difficulties in data population.

Prior to the simplification, a single product required 27 rows of data. With 140+ products this represented 3700 rows in the Excel model. For the planner to scan through all of these each week was a daunting and frustrating task. The simplification reduced this number to 10. Some of the rows of data were simply removed while others were moved to other sheets as reporting data or as input data.



Old Build Plan Format

New Build Plan Format

Figure 31: Simplification of the Build Plan Model

The next step in the process was to incorporate the Supplier Build Plan model. The model was used to calculate deltas between inventory, orders and targets. Sheets were moved into the Divisional Build Plan model for the Wafer, Assembly and Test planning.

Sort production would always be run first-come-first served[16] and therefore required no planning. A complete data sheet for inventories, targets, die per wafer counts, yields, and lead-times was created. The addition of lead-times and the movement of yield to the data sheet represented the largest change to the Phase III revision. Yield had been buried throughout the model and was therefore difficult to maintain. The addition of the lead-time adds the ability to calculate appropriate inventory targets that were previously all set to either three weeks for FGI or three months for unsorted die. The lead-times are also used to determine offsets needed to set build start dates through the supply chain. By Phase III we will finally have one single location for all supply chain data, the consolidated view.

Wafer Data

Valid Inventory Date WW47

BOH Wafer Data					Warehouse		Current Die Bank Wafer Inventory									Prev Month
Wafer ID	Fab	DPW	Fab TPT (wks)	WI Target (wks)	Unsorted	Sorted	FR	HK	T03	Giga	US	UK	Korea	P1	Wafer Total	Prev Month BOH
Wafer Type 1	Supplier X	1	12	6	5600	0									5600	3
Wafer Type 2	Supplier X	1,100	12	6	0	30									30	
Wafer Type 3	Supplier X	1,000	12	6	0	35									35	
Wafer Type 4	Supplier X	800	12	6	5	0									5	
Wafer Type 5	Supplier Y	900	12	6	17	0									17	
Wafer Type 6	Supplier Y	700	12	6	0	37									37	
Wafer Type 7	Supplier Y	1,100	12	6	11	10									21	

Figure 32: Phase III: The Consolidate Wafer Inventory & Data Sheet

Die Data

Valid Inventory Date WW46

BOH Die Data										Assembly Finished Goods + WIP									Test	
Product	MM#	Wafer ID	Primary Assm Site	Primary Test Site	Test Yield	Assembly Yield	Test TPT (wks)	Assm TPT (wks)	FGI Target (wks)	FR	HK	T03	Giga	US	UK	Korea	P1	SFGI Total	Test	FGI
Component SDF	836957	Wafer Type 1	FR	T03	0.96	0.96	1	1	2									0		34
Component SCF	837347	Wafer Type 2	HK	T03	0.96	0.96	1	1	2									0	223	
Component XYZ	835478	Wafer Type 3	US	T03	0.96	0.96	1	1	2									0		
Component OIU	836960	Wafer Type 4	UK	T03	0.96	0.96	1	1	2									0		

Figure 33: Phase III: The Consolidate Component Inventory & Data Sheet

From the two data sheets shown in Figures 32 and 33 the entire supply chain and inventory positions could be seen. This consolidation also helps in data maintenance, as only one sheet must be updated.

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[16] First-come-first-served refers to the production sequencing rule where jobs are processed in the sequence in which they enter the shop. Nahmias, ©1997

2.6.2.2 Build Requirements Automation

One of the goals of the Phase III was to develop a system that was self-managing. In the existing system developed through Phases I and II it was required that the planner enter the amount to build at each stage in the supply chain. To do this they were provided the build requirement, the current inventory position and target. By entering the requested commit, the model would show the resulting delta. The target was typically zero, but could vary depending on changes to the inventory target. To alleviate the need for this step two modifications were made to the Divisional Build Plan model. A dynamic inventory target was calculated based on the lead-times entered in the model and the model completed the calculation of the build requirement.

The inventory target algorithm follows the base stock model[17]. The amount of inventory target between sort and assembly would consist of two components. First, to cover the time it takes to replenish the wafer inventory a base amount is determined. This base amount is equal to the product of the average weekly demand and the lead-time of the foundries. The second component is the safety stock. This amount is used to cover for the variability seen in the demand. It is the product of the standard deviation of the demand over eight months, the root of the lead-time and a service level factor. The service level factor is based on the ratio of product margin and the cost of holding inventory. In the case of Giga margins are so high as compared to holding cost that the service level is set to 100%. This corresponds to a safety factor of approximately 3.08[11].

In the model each product has it's own finished goods inventory target and un-assembled die inventory target. The target is calculated using the base stock model. The lead-time is user entered in the main product data sheet. The average demand is built into a formula on the build sheet that dynamically calculates the average and standard deviation over an eight-month period. With this approach the planners only have to concern

[17] Simchi-Levi, Kaminsky, Simchi-Levi, ©2000 pp 52,53

themselves with the supplier lead-time that seldom changes. As demand changes weekly, the inventory target is automatically updated.

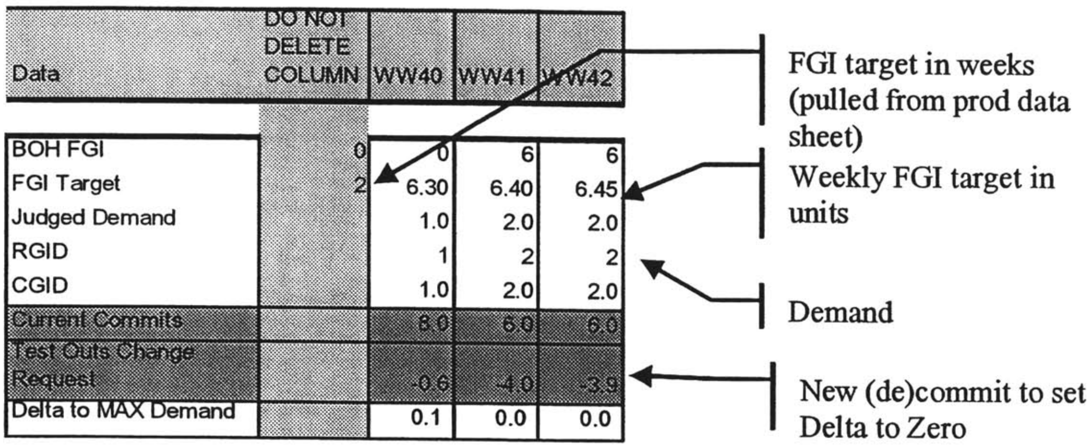

Figure 34: Phase III Inventory Calculation in the Build Plan

3 Results

3.1 Responsive Supply Chain Management System

The most significant result from this work was the implementation of a reliable, repeatable, and responsive planning system. The total time required completing the Build Plan Reset process was reduced by 50%, from four to two weeks. The total time required returning Customer Upside Requests was cut from one week to three days. The time required to update the Build Plan models with the required information in all processes was reduced from several days to minutes. The consolidation of the models, and processes and the reduction in time required has also reduced the labor burden. One planner can now handle the entire process.

3.2 Reliable Data Access and a Consolidated View

The new planning system now provides Giga full access to all of the data relating to the supply chain. The benefits are the ability of Giga to perform complete accounting of their inventory costs each month, to allow Giga to more accurately purchase and build wafers and final products, and to trend performance to targets over time.

The consolidated view also provides the needed foundation for scenario planning capability. This capability will allow Giga to test forecasts in demand as a what-if case to determine if their inventory positions are in fact sufficient to deliver to customers on time.

3.3 Inventory Control System

The work has provided Giga an inventory control system. This system allows the planners at Giga to set inventory targets which will provide promised service at the lowest possible cost. The control system is such that each product can have it's own inventory positions, which again helps in the optimization of the total supply chain.

3.4 Continuous Improvement Team

The work also provided the planning and logistics department with a team to handle continuous improvement in the department. The original task force put together to develop Phases I and II remains intact at Giga. At the time of this work they were moving ahead with a build to order system and long-term supplier relationship with T03. Prior to this work all efforts to improve business were disconnected. With this group now in place efforts to create change have a forum and method in which to be addressed.

3.5 Foundation for MRP/SAP

The development of a standardized planning system has the added benefit of providing Giga a solid foundation on which to possibly install SAP or another MRP tool. Had attempts been make to install SAP or other ERP/MRP system into Giga prior to this work a great deal of effort would have been required to either modify the ERP system or create business process matching SAP. With both of these efforts occurring at the same time it is reasonable to assume that the costs would have been greater.

4 Discussion

4.1 Design Strategy

The choice of design for the Supply Chain Management System was based on three factors. First was the need for a system to support both high volume and custom product development. Second was the need to implement a system at the lowest possible cost. Third was the need to implement a flexible system to support short product life cycles.

Had Giga's primary focus been the delivery of custom build to order products the system design would have been centered on the NPI process. In this case, however, it was clear that Giga's recent troubles in order management surrounded high volume products. The separation, however, of NPI from the high volume product suite and the development of a NPI planning tool did help meet both needs; high and low volume. The major difference between the two systems was that the NPI planning tool centered on cycle time or delivery time of each batch, modeling each process step including design and rework, while the high volume model focused on inventory positions to meet forecasted demand. If Giga were clearly a custom design manufacturer only the focus of the project would have changed, from perfecting the high volume system to perfecting the NPI system. At the time of this work only the high volume system was complete, with significant work remaining on the NPI tool.

At the start of the project Giga had the choice to make or buy a system. The choice to build an in house system was driven primarily by cost and time and partially by a desire to first standardize the business processes before buying an off the shelf software tool. The cost of implementing SAP or a similar tool was in the millions with a one to two year lead-time. The homegrown system was developed with no cost other than people hours and took less then six months.

The third component to the design strategy was to deliver a system that was flexible and easy to use. With a great deal of uncertainty in product mix and volume the system needed to be able to support changes in products and suppliers. It was decided that a heavy investment in a tool such as SAP would lock in a business system that would not necessary support these flexibility needs. A homegrown Excel based tool, however, was seen as easy to use and modify if necessary. It also represented the lowest cost solution, off-setting the risk associated with the project.

4.2 Three Phase Change Management Process

The three-phase process demonstrated in this work is a practical means to redesigning business systems, such as the Supply Chain Management process. The process strives to first establish a baseline repeatable system, second a reliable and accurate system, and third a quick and low cost system. By first building a repeatable system you accomplish two goals; the system become measurable as it is repeatable, and some change is started building momentum for the future phases. With momentum and a standard baseline it is much easier to see where the system needs improvement. In the second phase it is important to focus only on making the system reliable, not quick. As described in Chapter one the system did have a level of automation in the auto download of the forecasted data, but it was placed into a complex and error prone model. This automation did speed up the process but required a significant amount of rework as the model was improved. Only after the system has been made reliable and accurate is it appropriate to move to automation or other means of speeding up the process.

The three-phase process can also be applied in the context of a company's emergence into high volume standardized products. First, they need to become repeatable, delivering new products consistently. Second they need to be reliable, that is the products produced must work and work correctly. Finally the products must come to market quickly. Giga's needs or the needs of an emerging company and the three steps can be mapped to the development of the Supply Chain Management structure. First, Giga only needed a custom build system, where each order was managed independently. This type of process can be managed effectively with email and some basic software tools. Giga was very successful with this system, using their homegrown Production Control System and Navision. Second, Giga needed to be reliable. The homegrown system was not reliable enough to manage complex and frequent orders. And finally, once Giga has established itself as a true high volume producer it would be appropriate to install an off the shelf ERP system. But without going through the basic steps and following the three-phase process the cost and effectiveness of any system could be lost.

4.3 ERP/MRP Requirements for Emerging Companies

ERP and MRP systems can be very expensive. These systems are often purchased and installed without careful study of the general needs and strategy of the company. Often they are bought more for their apparent benefits than business fit. With this attitude it is not surprising that previous research reported that 63 percent of MRP applications studied cost as much as $5 million without any tangible benefits[18].

Giga, just prior to this work, was in conversations with Intel to install SAP. The roadmap to installation was shown to be over one year with a price tag approaching several million dollars. The price tag alone was close to Giga's quarterly earnings and did not include an MPR module or the cost of making the system fit Giga's business processes. What Giga needed was control over their existing systems. The approach I present in this work provides the foundation for an emerging company.

The development and choice of system used must also fit the business strategy as well as their immediate needs. While Giga is on the verge of needed a fully blown ERP system it is still not clear that SAP or another large system is appropriate. The optical networking components market is characterized by dozens of different products, each being developed, brought to market and ended in less than a year. The rapid introduction, ramp and the obsolescence of the products make Giga a "High Clock Speed" [19] business. As a high clock speed company Giga must be prepared to rebuild and redesign the structure of their supply chain to meet the changing needs in the market place. The planning systems and tools should be designed to meet the needs. For example, new products must be very easy to add and delete. The ability to manage upside quickly with a better understanding of capacity is also important. New suppliers may need to be taken on

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[18] R.G. Shroder, ©1981

[19] C. Fine, ©1998

based on the need for unique fabrication processing skills. In a high clock speed company the architecture of the products will change rapidly, from being fully integrated to modular. These changes will change the structure of the supply chain. In fact at the time of this writing the Optoelectronics industry, specifically Ethernet modules, were becoming more and more integrated. With a fixed MRP/ERP system these changes could be very difficult to manage.

The advantage of first developing the planning systems in Excel is the ability to easily change modify it. While excel is clearly not robust, it is flexible, cheap and easy to use. Emerging companies must consider their stage in growth, their market needs, and their current processes before leaping into decisions on purchasing ERP or MRP systems. These companies must also consider that perhaps a homegrown system with focus on reliability, repeatability and responsiveness may be sufficient to bring them into the next phase.

4.4 Materials Requirements Planning

MRP systems are not without pitfalls. A traditional MRP system is a closed production system with two inputs; (1) the master production schedule and (2) the relationships between the end product and the components that go into making it. With a master schedule all builds required to support the final product are cascaded back based on predetermined lead-times. This system depends on the certainty of both the demand and the lead times in order to deliver the right quantity on time. However both lead-time and demand are uncertain, changing every week[20].

The solution to this problem in the design of the Supply Chain Management system at Giga was two fold. First, and most importantly, forecasts were given to all steps[21] in the process. This way each node, or supplier in the chain, could see and plan for future changes. They were given a firm four-week schedule plus an eight-month forecast. The suppliers were expected to build each week in sequence, but in any order during the

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[20] Nahmias, Steven ©1997. pp 360 'The short comings of MRP'

[21] Steps refers to both internal Giga manufacturing steps, such as Assembly or Test and to Suppliers

week. The second piece was the implementation of planned inventory. The inventory can be used to absorb some of the fluctuations in the demand. The inventory levels were dynamically sized based on forecasted demand to align them with future changes. When demand dropped, inventory would temporarily increase and orders would stop. When demand picked up the suppliers would once again start manufacturing. There was no penalty for slightly over building and likewise with the inventory, no penalty for under building.

4.5 The move along the Hayes Wheelwright Curve

The characteristics of Giga just prior to and during this work were one of an emerging high volume producer. They had an intertwined planning system including legacy systems, new and old products, low and high volume. Their planning system primarily grew up to handle batches. Batches are typical for new products as only a discrete amount of material is needed versus high volume products which, as discussed in Chapter Three, must be ordered in advance to some forecast and held in inventory. This work has helped in separating Giga's product suite and in providing them with a high volume product planning and management system.

Giga's transformation can be plotted on the Hayes-Wheelwright diagram[22], showing the relationship between manufacturing processes and product types. Giga's new product development falls in the upper left hand corner of the chart, where the product is custom built and ordered only in low volume. The high volume products, on the other hand, are found in the lower right hand corner of the chart, where the products are standardized and manufactured in high volume. The production of the low volume new products is best done in a job shop environment, while high volume is best suited for continuous flow manufacturing. Giga, however, had been handling both product types together; neither in a job shop batch format or in continuous flow, as shown in the Figure 35.

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[22] Hayes and Wheelwright, ©1979. Mapping of Giga's transformation reproduced with permission from materials created by Chris Richard, 2001. Subcon refers to a supplier.

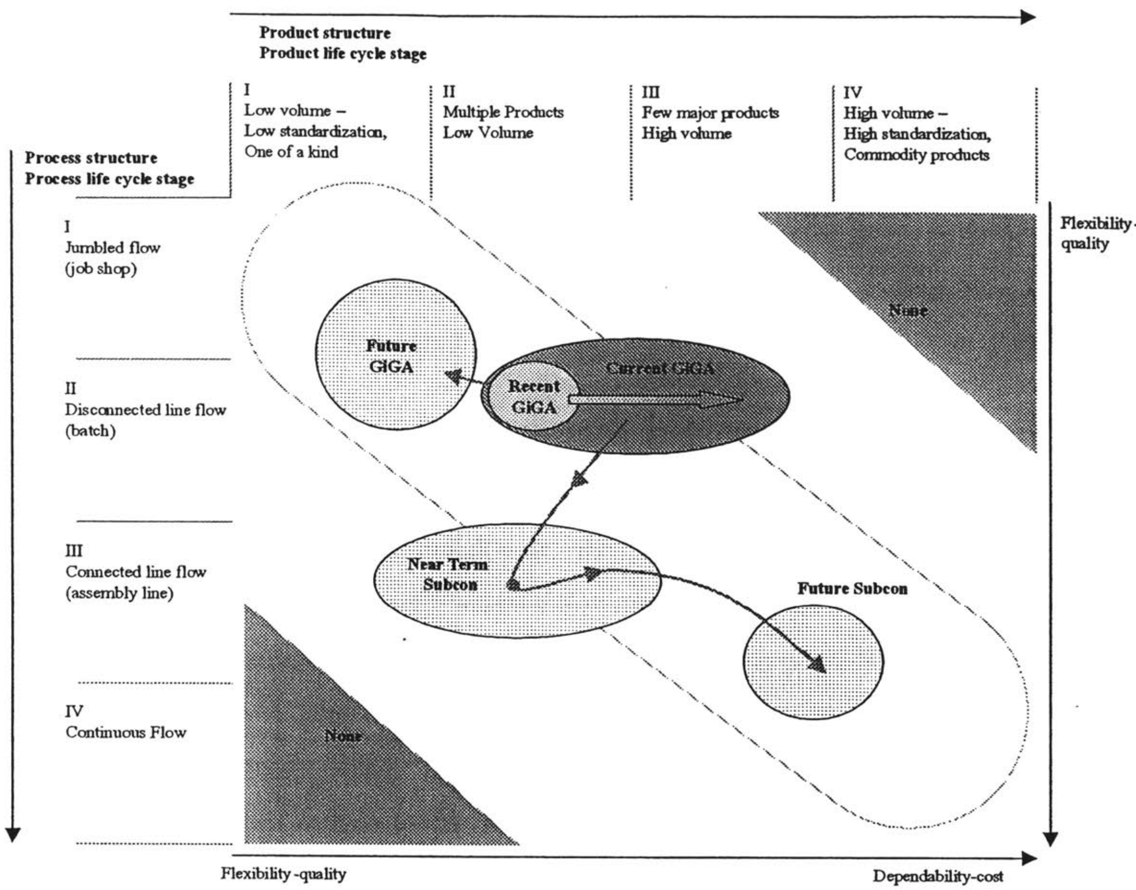

Figure 35: Hayes-Wheelwright Representation of Giga's Manufacturing Changes

Giga's move to the right hand side of the chart, Figure 35, was placing them outside of the optimal operating space. The work to redesign their Supply Chain Management System and the consolidation of their Suppliers has moved their position back down to the left. As volumes increase and with future Phase III plans to move to a build to order system Giga's manufacturing strategy is moved further to the lower right hand corner, with high volume and continues flow manufacturing. Also shown in Figure 35 is the move of a 'Future GIGA' to the upper left hand corner of the chart. This represents the consolidation of all NPI to Giga. NPI will be manufactured as before, in small batches and in a job-shop environment. The separation of NPI from high volume is a key component to Giga's future growth, allowing them to simultaneously design new products and manufacture established ones in high volume.

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6 APPENDIX

6.1 *Appendix A: Build Plan Calculation Details*

Figure i shows the calculations completed in the Division Build Plan model. The shaded box is the output of the model. Figure ii shows the calculations completed in the Supplier Build Plan models. As Giga's internal manufacturing was managed separately Figure iii shows the calculations done in Giga's Build Plan model.

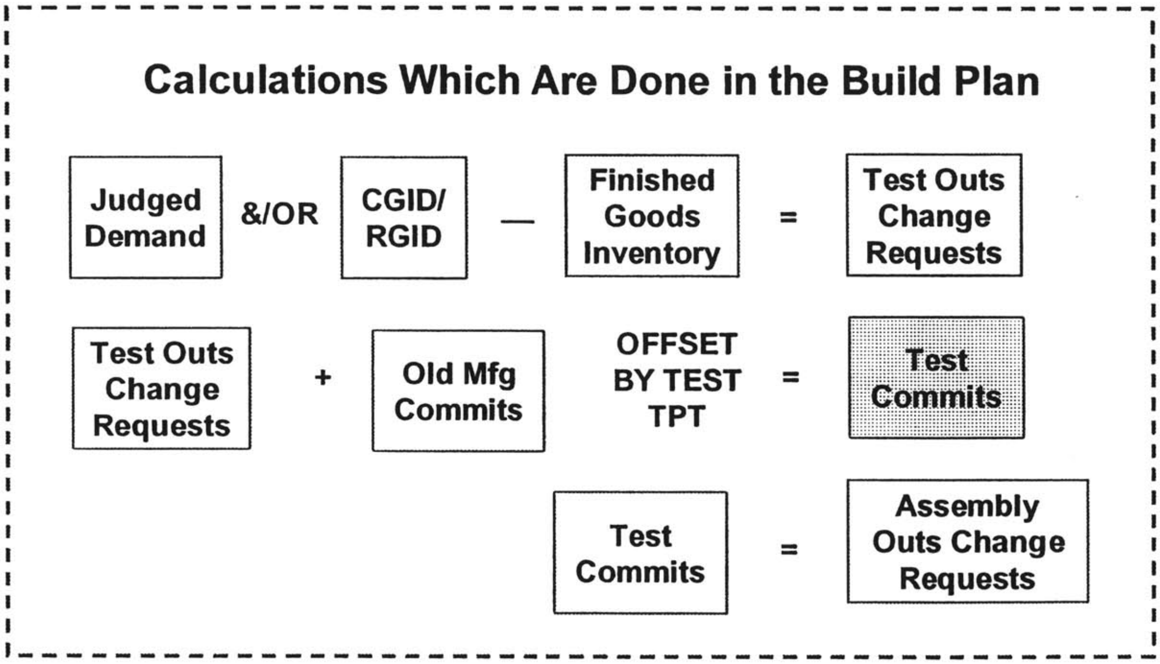

Figure i: Division Build Plan Calculations

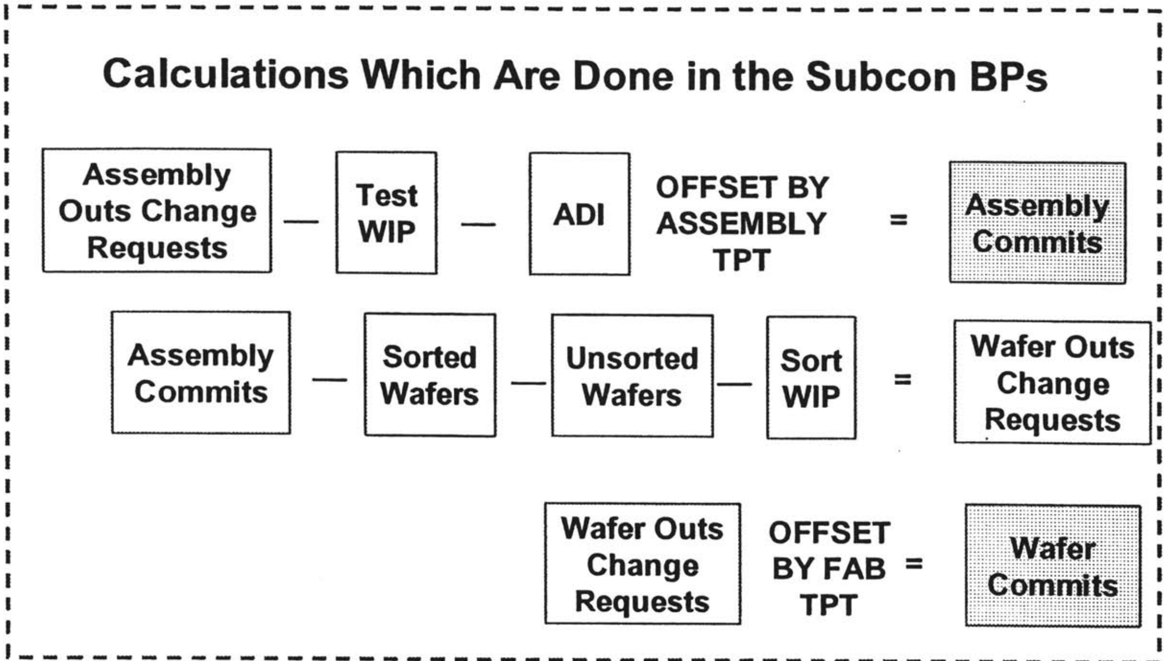

Figure ii: Supplier Build Plan Calculations

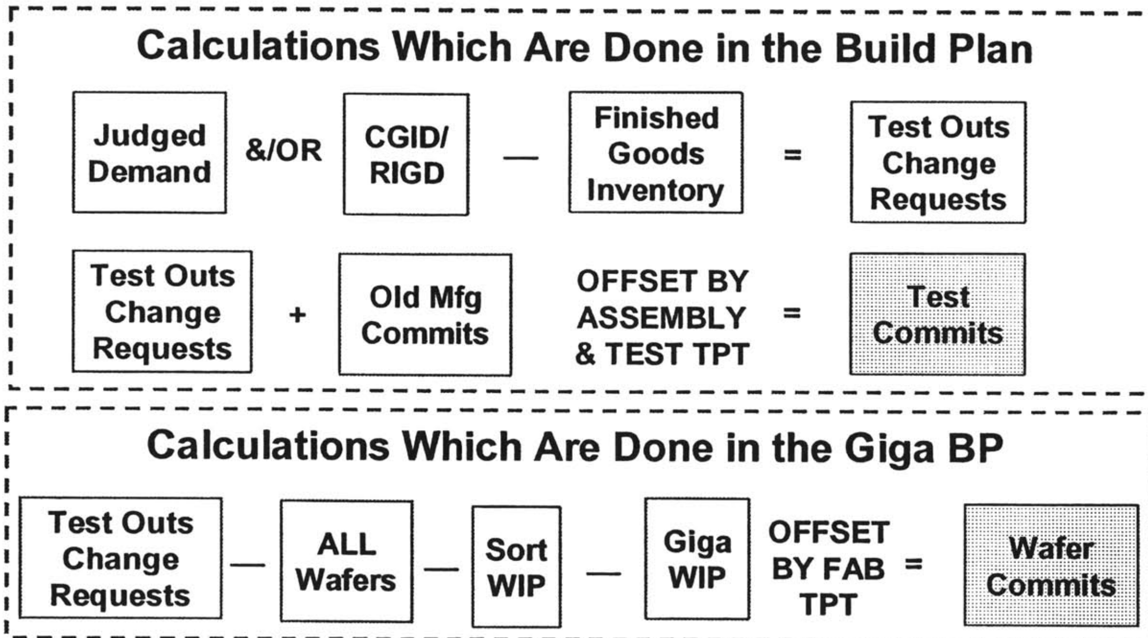

Figure iii: Giga Build Plan Calculations

6.2 Appendix B: Detail/Enlargement of Giga's Position on the Hayes-Wheelwright Diagram

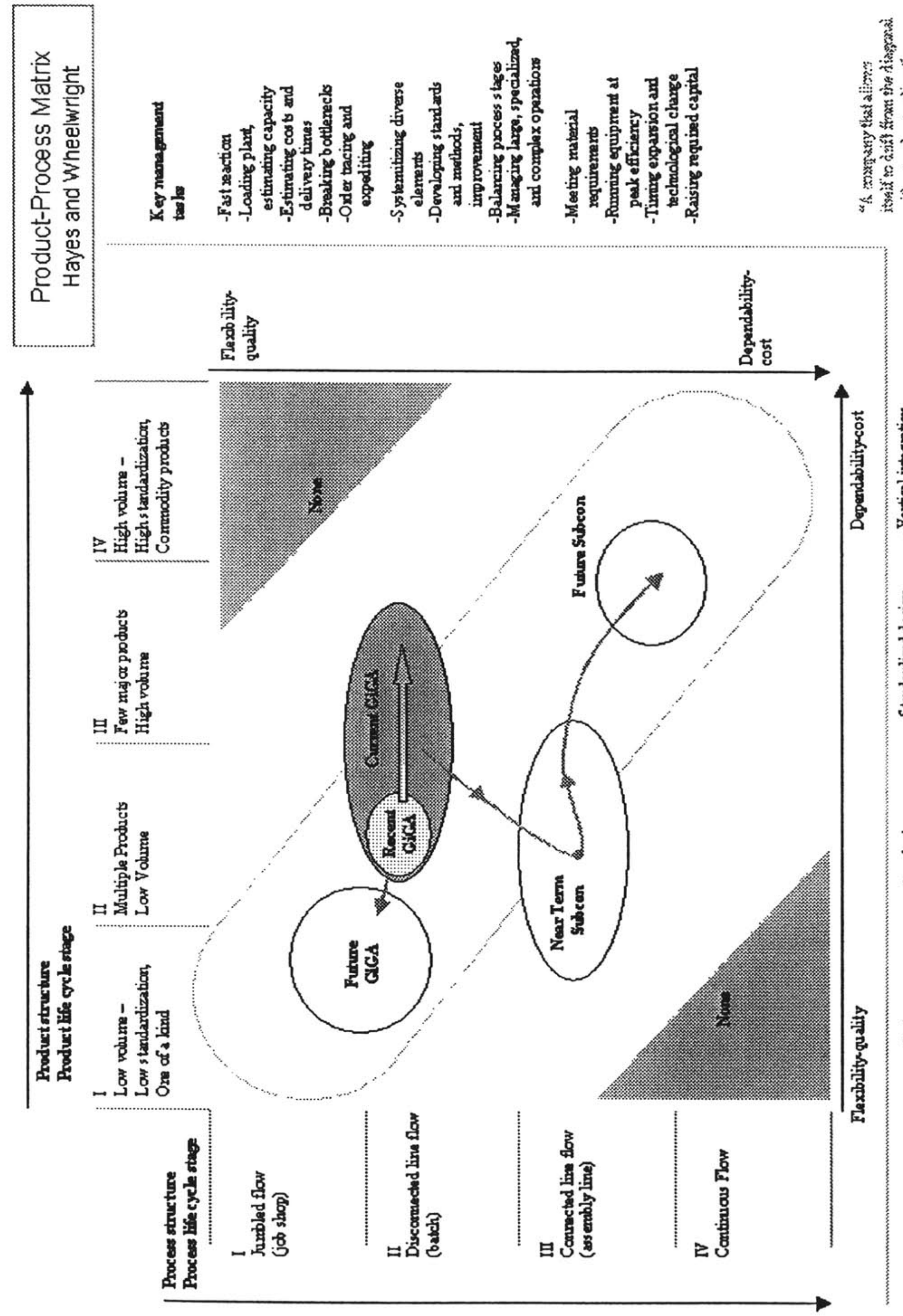

Figure iv: Position of Giga on the Hayes-Wheelwright Diagram