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A SUPPLY CHAIN STRATEGY FOR PATIENT DATA MANAGEMENT PRODUCTS

by

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Submitted to the Sloan School of Management
and the Department of Civil and Environmental Engineering
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and
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ABSTRACT

The market for patient data management products (a subset of Hewlett-Packard's Patient Monitoring Division's product set) is changing. These products have traditionally been made with custom hardware and embedded software, and manufactured in house, that is, by HP. However, for these products, HP has made a strategic decision to build them using industry standard hardware components whenever possible. This is, in effect, outsourcing the manufacture of hardware components. HP's medical information management tools are largely computational, so HP can enjoy much faster increases in capability with minimal product redesign by using industry standard computation and data handling hardware. HP sees that to stick with custom-designed and built hardware would leave itself at a disadvantage relative to its competition and the expectations of the marketplace.

Like many other companies and HP divisions, PMD has been evaluating its supply chains, considering where it might increase or decrease the level of outsourcing. PMD has already taken a step away from vertical integration by using industry standard hardware as a base for many of its systems. From here, PMD must decide at what other points in the delivery process to outsource processes, as well as how to transition from its current processes to the new structure.

The goal of this thesis is to recommend supply chain improvements, recognizing future market trends and where future value will exist. It will be contended that value (and therefore lucrative margins) will be created in software design, as well as in process design for medical software implementation; hardware handling will not carry value once current technical barriers are overcome. This understanding should guide HP's sourcing decisions. The thesis will go on to recommend and justify specific sourcing changes for PMD.

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Chapter One : Introduction

1 Situation and Goal

Hewlett-Packard's Medical Products Group, headquartered in Andover, Massachusetts, is a leading provider of clinical measurement and information solutions, and services and support for the healthcare industry. The group had 5,300 employees worldwide and revenues of $1.4 billion in its 1996 fiscal year. The Patient Monitoring Division (PMD) provides a variety of products that acquire and process patient data in acute care settings, generally in hospitals. All of PMD's products were traditionally made with custom hardware and embedded software, all manufactured in house, that is, by HP. This is no longer the case; many are now being built primarily from industry standard hardware components.

Patient data management products are a subset of PMD's product line. They are one step removed from the patient; these products manage, store, display, and analyze patient data acquired from other monitoring products. For patient data management products in particular, HP has made a strategic decision to use industry standard hardware components whenever possible. PMD intuitively recognizes the value in leveraging the strides constantly being made in computing hardware. HP's medical information management tools are largely computational, so HP can enjoy much faster increases in capability with minimal product redesign by using industry standard computation and data handling hardware.

Like many other companies and HP divisions, PMD has been evaluating its supply chains, considering where it might increase or decrease the level of outsourcing. PMD has already taken a step away from vertical integration in its use of industry standard hardware as a base for many of its systems. From here, PMD must decide at what other points in the delivery process to outsource processes, as well as how to transition from its current processes to the new structure.

HP's decisions in these matters must be based on where real value can be added in the supply chain. In the future customers will value product modularity and flexibility more than they do today, due to increased technical sophistication and familiarity with the components of patient data management systems. The structure of these products will be driven toward modularity (that is, an ability to purchase only portions of the product functionality or componentry) by market forces that were set in motion by HP's decision to use industry standard

hardware in them. Going forward PMD must select the pieces of a modular-product supply chain that will best support ongoing strategic advantage for HP and will provide the best sales margins.

The goal of this thesis is to recommend supply chain improvements, recognizing future market trends and where future value will exist. It will be contended that value (and therefore lucrative margins) will be created in software design, as well as in process design for medical software implementation; hardware handling will not carry value once current technical barriers are overcome. This understanding should guide HP's sourcing decisions. The thesis will go on to recommend and justify specific sourcing changes for PMD.

2 How this Thesis is Organized

This paper is designed to lead the reader through a market-based argument and to an understanding of what considerations should drive PMD's decisions in outsourcing for its patient information management products, as well as how HP might implement those decisions.

Chapter 2 provides a background in the industry and in HP's particular situation with patient data management tools. It also makes clear the limited scope of this analysis, though it is hoped that this analysis will help HP in further analysis of other products and sourcing decisions.

Chapter 3 discusses the outsourcing (make/buy) decision itself for these products. It provides some structure based on an understanding of PMD's particular situation, as well as based on academic writings. By the end of the chapter the reader should be convinced that HP ought over time to outsource its hardware and hardware-software integration, but retain control over its software design and process design for integration, testing, and installation.

Chapter 4 discusses the tradeoffs HP faces in implementing its make/buy decisions, whether to make the change sudden or gradual, and whether to transition all information management products to an outsourced hardware model together or in smaller subsets.

Chapter 5 presents recommendations to HP based on the analysis. It suggests a course of action and the cost/benefit priorities that such a course involves. It further discusses changes that HP must make in its organization and culture in order to be successful in following the suggested approach. It includes some advice to HP for its supplier selection process. Finally, it offers a suggested timeline for implementing the recommendations.

Chapter Two : Background

This chapter discusses the industry environment in which PMD operates, outlines the scope of this thesis, and describes some issues that affect PMD's sourcing decisions.

1 Patient Monitoring

Industry Structure

The patient monitoring industry has traditionally been relatively slow moving and conservative. This is primarily because of its customers. Hospitals and clinics, doctors, and administrators are generally conservative, unwilling to risk patient lives on unproven technologies. Also, patient monitoring systems are major capital investments and may remain in use for many years. These two particulars of the industry combine to make product life cycles long, on the order of 8-10 years. This is despite the fact that the technology level in the systems is high, which tends to make product life cycles short; specific components within PMD's products may themselves have life cycles of less than 6 months.

The industry is fairly tightly regulated by the Food and Drug Administration (FDA) in the United States and other agencies worldwide. The FDA has defined good manufacturing practices (GMP) for methods, facilities, and controls used for the manufacture, packing, storage, and installation of medical devices. Manufacturers must prove to the FDA and other agencies that their processes are well defined, and that their devices are being manufactured strictly according to those processes every time. However, the specifics of GMP are not entirely clear in this world of industry-standard computing hardware and custom software. Opinions differ within HP regarding how much control is required over the software image, installation activities, and the variety in the hardware used. For the purposes of this thesis, we will assume that it is possible to design and define processes to a sufficient level of detail that they can be performed by a non-HP partner.

Most revenue comes from large orders, usually from hospitals and clinics that are either expanding or renovating facilities. Some other large orders are for replacement of older monitoring systems. Because these large orders are usually part of capital planning, a short delivery lead-time is not critical. However, the configuration details and desired delivery date may change quite a bit right up until shipment. Furthermore, customers consider it extremely important that everything be delivered on the promised delivery date. Customers don't want late

delivery of their monitoring technology to hold up the opening (or re-opening) of a hospital wing, for example.

There is a distinction between independent hospitals and larger companies that may own many clinics and hospitals. The primary difference between these operators for purposes of this thesis is in their levels of technical expertise. Some large companies have information technology departments that manage every aspect of hardware and software within their facilities. They likely have negotiated company-wide contracts with hardware and software providers, and they may perform all of their own integration and installation activities. They generally have significant bargaining power versus HP, and can demand the kinds of products they want. Independents and smaller companies may not have a very sophisticated information technology function. They are more likely to need (and be willing to pay for) HP's full-service approach to medical systems delivery. According to the American Hospital Association, hospitals are roughly equally split between independents and larger management bodies, which suggests that both kinds of customers described above will continue to exist for some time.

The shift toward modularity in patient data management products is and will be at least in part due to increased sophistication of larger institutions. For example, it is now possible to purchase only selected analysis algorithms in a data management product, where previously all algorithms might have been bundled into the system for efficiency in design and integration. Customers are becoming less willing to pay for what they do not need or want. As it becomes more technologically feasible for monitoring providers to modularize their products, they are working to provide an "a la carte" product solution, whether implemented in separate products or in a single product, configured to customer specifications. Effort spent on modularization is clearly not spent improving the products in other ways; to some extent this market change is holding up product advances. However, the drive toward modularity is coupled with the increased leverage of industry standard hardware, so patient data management products as a whole are probably improving faster now than they were ten years ago.

HP's Position

> "More than 80 companies produce patient monitoring products, but they all trail the Hewlett-Packard Medical Products Group" – Health Industry Today (May, 1997)

HP has been on top of the medical monitoring market for some time, and is generally seen as an innovator in products and services. Because PMD is by far the largest manufacturer of patient monitoring equipment, it has had the ability to offer a wider range of products and services on its own. However, HP has also made strategic alliances with medical analysis

software vendors as well as other equipment vendors to broaden its offering. Customers see HP as a single source for the largest range of patient monitoring tools and systems.

HP also leads the industry in redefining the products that customers need and that it provides. It is a founding member of the Andover Working Group, a consortium of over 200 application and equipment vendors, healthcare providers, systems integrators and consultants. The Group's goal is to develop standards for and deliver inter-operable, object-oriented software for healthcare applications.

Manufacturing Strategy

At a high level, PMD's manufacturing strategy has been designed to provide quality products, ensure GMP, and manage inventories effectively. PMD has only three manufacturing sites for its devices worldwide. It maintains multiple manufacturing sites for its more important products, but focuses each of its sites as a center of excellence for particular product types.

HP overall is a leader in supply chain management, particularly in the technique of postponement, or manufacturing generic products as far along the supply chain as possible, only customizing them for particular customer needs once customer demand and product mix have been firmly established. PMD works to incorporate postponement into its manufacturing strategy primarily through configuration – the same software can be used for multiple systems, and the customer-specific configuration is created during software integration, very shortly before the products are shipped.

2 Scope of Analysis

The scope of this thesis is broad in terms of subject, but it only entails a portion of PMD's product line. The content of the analysis is oriented toward supply chain structuring, and how HP might source its products over the next several years. It centers on manufacturing, but the arguments of Chapter 3 depend on movements in customer markets, and much of the implementation depends on high level organizational changes and a refocusing of Research and Development activities. However, the technical concerns that HP must address to implement the recommendations that follow are beyond the scope of this thesis.

A *supply chain* is the network of people, processes (designed processes in practice), and material involved in taking raw materials and providing a product to a customer. It is most commonly described as a series of processes, with people and material implied. The supply chain in scope of this thesis is specific to only certain of PMD's products.

There are three major product functions in the patient monitoring business, listed here in order of increasing scope (this thesis focuses on the second one):

- **Sensors and Monitors** – These products acquire data from patients directly. A variety of sensors can register such patient information as pulse and respiration rates, temperature, blood pressure, gas measurements, and oxygen saturation in the bloodstream, and provide that information to bedside monitors. These devices are attached to and often travel with patients. They often have displays or hardcopy recorders attached to them, but they lack network capabilities beyond the ability to send data over a proprietary network to patient information management tools.
- **Information Management Tools** – These products deal with data provided from monitors. They manipulate, store, analyze, move, and display the data. They often form the interface between proprietary monitoring networks and industry standard hospital information networks.
- **Clinical Information Systems** – These systems manage patient data at a higher level, although they often interface with patient data management tools. CIS are designed to manage all relevant data for the patient's stay in a facility, including billing information, treatments, physician data, and an appropriate subset of monitor data. These systems are generally modular, with software able to run on multiple hardware platforms and able to interface to a variety of other products.

Figure 2.1 illustrates this categorization of patient monitoring products.

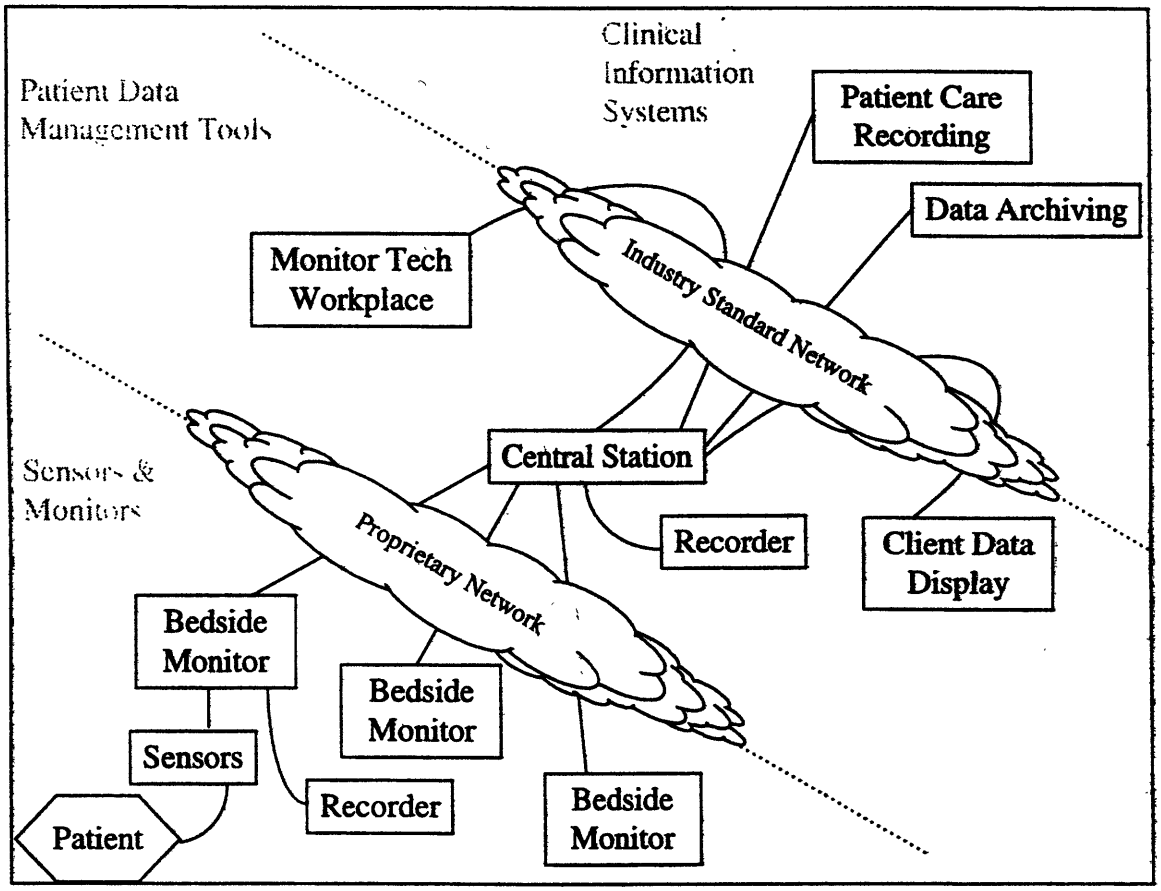

Figure 2.1: Categorization of Patient Monitoring Products

This thesis is only concerned with patient information management tools, situated between monitors and clinical information systems. This is because the author's experience within PMD has been focused on data management tools, but also because these products will provide the richest ground for discussion of where value is truly added, and what HP should do to maximize long-term strategic advantage. For sensors it is agreed within PMD that manufacturing them is a core process competence; for these products HP will definitely remain more or less vertically integrated. In certain business areas within PMD, such as CIS, the software applications are the key value added. The implication of this is that software can be sold separately from hardware, which increases the flexibility and management challenge in the supply chain.

Throughout this thesis, generalizations about PMD's products should be understood to be directed only toward patient information management products, unless otherwise specified. Applications to other parts of PMD's product line, while they may prove valuable, are outside the scope of this thesis.

3 Patient Data Management Products

Patient data management tools allow for the analysis of patient monitor signals both by software algorithms and by people. For example, using a central station a nurse might identify something unusual about a patient's heart rhythm (or the tool might identify it *to* him) and ask a cardiologist to access and review the "event" data from a client data display in her office.

The most common of information management tools is the central station, which receives data from several bedsides within a ward, and displays it to the doctors and nurses managing the ward. Although they are a subset of patient data management products, central stations show the technical attributes relevant to this thesis. Central stations manage many activities at once, in real time. They may do any or all of the following:

- Receive patient data signals over a proprietary network from one or more bedside monitors
- Analyze the signals for abnormal conditions, sounding alarms if patient data exceeds established conditions for concern
- Display the patient statistics to nurses, doctors, and monitor technicians using a graphical user interface
- Route data to a recorder, which prints a hardcopy report
- Route data to other patient data management products, such as client data displays (remote systems for data display only) or monitor tech workplaces (systems that allow technicians to monitor many patients at once).
- Store a local version of the data (to maintain a copy if the network goes down)
- Send the data to an archiving server
- Interface to patient care recording systems to log events relevant to the care record.

A central station might consist of a high-end, dual processor PC with enhanced video and sound cards installed, a proprietary network card installed, and the speaker volume control removed. It could be running Windows NT and HP's proprietary software, which has several HP- and third-party-developed software algorithms designed to analyze waveforms (data signals) from bedside monitors. It would likely have with it a large monitor (or two), a recorder/printer, a trackball for easy control, and an uninterruptible power supply (UPS). The older, integrated systems would have been a single processor/monitor unit, built from fully custom hardware components with a single-purpose application/operating system, but with similar external accessories.

The supply chain for patient data management products is illustrated in figure 2.2.

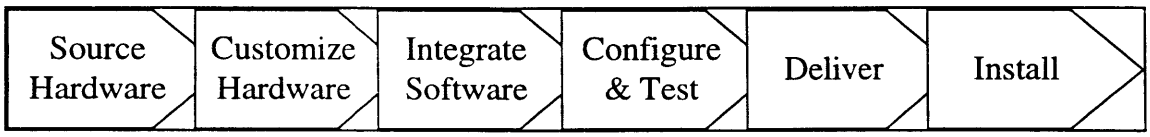

Figure 2.2: Supply Chain for Patient Monitoring Products

The three links "Customize Hardware", "Integrate Software", and "Configure & Test" are sometimes referred to together and more simply as "Integration & Test". Customizing hardware consists of the installation of proprietary hardware extensions, such as the proprietary network card, as well as some modification of the hardware itself, such as the removal of a PC's speaker volume control. Integration of software involves loading of the operating system, specialized hardware drivers, and the application software in a generic form. Configuration involves customizing the software for the customer's application, enabling the options that the customer has purchased, and testing the configured system to ensure that it is functioning properly.

The links are all interdependent, more than simply with respect to sequence. They depend on each other technically as well. For example, as shown in the next section, sourcing hardware can be very difficult if the proprietary hardware and software are particularly sensitive to variation in the standard hardware. Also, design of the software can significantly affect the amount of technical expertise required to integrate, configure, and test the software. Before the management of this supply chain can be outsourced, the integration and test processes must be made both more robust to hardware variation and more simple and self-contained; this is primarily an issue of software design improvement.

4 Current Challenges and Issues

HP's information management tools are not easy to build with industry standard hardware. Software performance is critical, and it must perform in real time every time. Although bedside monitors are designed to set off alarms if a patient's signals move outside acceptable parameters, it is often the information management tools in the hallway that are being actively watched by medical professionals. In some cases (such as telemetry monitors that allow patients to move about the hospital with only a small transmitter) there is no bedside at all, and information management tools are the only source of alarm should something go wrong with the patient. Healthcare providers (and HP's reputation) cannot afford to have technical problems arise in acute care. HP's traditional strengths in hardware development and manufacturer no longer help as much when the hardware is outsourced.

Patient data management tools are intense, real-time, specialized applications. As currently designed, they consistently use considerably more of a processor's capacity than is used by more demanding office users. As faster chips and data buses are developed, this will become less of an issue, but currently it makes products extremely performance-sensitive.

Hardware component performance is often not guaranteed to the strict tolerances required by PMD at the upper levels of the performance spectrum. The cost-management approaches of major hardware manufacturers are good for consumer and business applications, but it puts performance at risk for PMD's applications. PMD has been forced to take a "try it and see" approach to the hardware it uses. One lot of hardware components may work with the current software, but the next may not. This is commonly because of changes to lower-level components within the hardware. The changes are considered minor enough that for most purposes the hardware is identical, but they may cause unacceptable software performance problems for HP.

For example, in one industry standard computer used by PMD, a vendor began shipping machines with new hard drives that have more capacity and a faster data transfer rate. The vendor considers this an enhancement, and most customers would appreciate such an enhancement. However, with the increased data capacity, the initial time required to access new data blocks increased. This increase created unacceptable delays in some software functions, requiring that PMD modify its software to accommodate the "improved" hardware. PMD must either control its sources or develop its products such that they are robust to the variations that naturally occur in industry standard hardware.

PMD is a small user of computing hardware, compared to the major suppliers in the industry standard hardware market. As such, PMD has limited leverage with its suppliers to control the hardware that is shipped to it. At the very top end of the hardware performance spectrum the market is much smaller, and PMD has relatively more leverage; however PMD's volume never exceeds 10% of its primary hardware supplier's total. When problems arise, suppliers are often willing to help, but they will not freeze hardware configurations for PMD's benefit at the volumes PMD requires.

HP's current work-around for this situation has been coined "homogeneous lot verification". For certain products and components, it negotiates with vendors that they will provide homogeneous lots – that is, that all lower-level components will be the same for all items in each lot. PMD then orders hardware in month-sized lots with several weeks of lead-time.

Engineers verify the homogeneity of the lot, test the hardware in great detail, and ensure that the software will work properly with it. Once the tests are complete, PMD can use the entire homogeneous lot and expect no configuration problems. If there are problems with a lot, PMD uses the long lead-time remaining to make changes to its software or get the problems fixed by the vendor. This way PMD can keep shipping with good hardware while it resolves any issues.

Homogeneous lot verification creates a number of sub-optimal results:

- Demand must be planned months in advance, and investments in component hardware are locked in long before customer demand is clear.
- Inventory investment is substantial. Hardware is a substantial part of the cost of PMD's finished systems, and maintaining weeks of safety stock inventory creates large carrying costs. Although PMD enjoys the forecasting insurance provided by the long lead-time, the cost is not warranted.
- Due to the special accommodations asked of component vendors, and the large lots required for efficient testing, it is difficult to maintain multiple sources for components. Supplier shortages are a particular concern at the high end (top 10% in performance) of the industry standard hardware market.

The costs resulting from these challenges outweigh many savings that might be gained through novel sourcing of PMD's products. Moreover, it will be impossible to undertake more radical supply chain changes without resolving these issues, as it would be unreasonable to ask (or pay) for an outsourcing partner to take on the processes and inventory associated with lot verification.

This chapter has described the PMD's environment and product line. It has outlined the supply chain for patient data management products, and described some of the technical challenges currently facing HP with these products. These challenges have made long-term strategic analysis of HP's supply chain difficult. However, the strategic direction HP should take relies on solutions to these issues. The remainder of this thesis will show how practical steps that PMD can take over the next few years will help it resolve technical issues by adding to its learning while creating internal pressure for HP's engineering talent to address those issues. The next chapter will describe strategic drivers of the outsourcing decision, and relate them to these technical issues.

Chapter Three : The Decision to Outsource

Outsourcing is often considered as primarily a cost-cutting measure. This chapter will present a case that relies on strategic considerations rather than on any particular costing analysis. Making decisions based on cost alone is risky because it ignores the primary reasons people buy HP systems – functionality, service, and reliability. However, the justification in this chapter arises out of a supply chain costing model developed by the author for Hewlett-Packard in 1997; the model is summarized in Appendix 1. The chapter will first suggest that HP will eventually be forced to offer modular software products that customers integrate themselves. It will then argue that in the future design of software as well as integration processes will be the main drivers of value. Finally, it will suggest that HP can outsource products as a step toward developing the right competencies in the world of unbundled products.

1 Bundled and Unbundled Software

Right now most medical monitoring software is sold as a *bundled* package with hardware, software, and some services included, for a single price. Most tax-processing software (for example) is sold *unbundled*, and the user purchases it expecting to provide his own hardware and to install it himself. Unbundled solutions may be sold "off-the-shelf" or customized, but by definition they are sold "a la carte".

For PMD today, bundling means that it provides monitoring software fully integrated into hardware, fully customized and configured to customer specifications. Another division provides installation services (bundled into the sales price), completing a turnkey solution for HP's customers. In addition to the fact that medical information solutions have generally been sold bundled, bundling has some advantages:

- It enables complete control of the product and the implementation of the design, in accordance with Good Manufacturing Practices.
- Customers often prefer a turnkey solution, with a single quote, order, delivery, and invoice, and installation team.
- Many customers would not be able to integrate and implement software solutions on their own.
- HP is known in the market as a great single-source vendor; providing turnkey solutions is a core competitive advantage for PMD.

HP will probably provide turnkey solutions to at least some of its customers for a long time to come. Note that turnkey systems can be built from unbundled, modular components, so that HP can continue to provide turnkey systems whether or not it builds modular products and offers them to other customers unbundled.

However, the unbundling of medical software solutions is inevitable. Market forces will eventually force PMD to offer unbundled software solutions. Customers will be able to purchase software only, or combinations of software and hardware and services as they see fit. A number of forces will contribute to the change:

- Large, savvy customers know that they can source and install standard hardware more cheaply than can HP's field organization.
- Once customers can easily identify the hardware components and price them out themselves, the value perceived in the bundle may be reduced below HP's delivered cost, so the software will need to be priced separately. Some customers will demand that they be allowed to integrate and install software themselves, on their own hardware.
- PMD should expect its competitors to push the market in this direction by offering unbundled products themselves. To the extent that providing a turnkey solution is HP's competitive advantage, competitors can diminish that advantage by shifting customer expectations toward unbundled products, provided that their prices and quality are at least as good as HP's. Competitors may be able to increase perceived value by offering exactly the components that customers want at better prices.

As mentioned earlier, HP in fact started the trend toward unbundled software by leading the patient monitoring industry in the use of standard hardware. By building systems on industry-standard hardware, HP was increasing its advantage by leveraging technological advances and cutting costs; but it was also modularizing the product, shifting the product's value away from the particular hardware provided toward the software itself. Once the industry follows HP's lead, customers will value the system purely by the software, and will in many cases be unwilling to pay PMD for anything but the software.

> "An innovation that raises a firm's competitive advantage may eventually undermine industry structure, if and when the innovation is imitated." -- Michael Porter (1985)

Changing Industry Structure - The Double Helix Model

PMD has lived in a vertically structured industry for the past three decades, but the industry is becoming more horizontal, i.e. the products are becoming less integral and there are

more stages (and competitors) in the supply chain. This changing structure is not random, but rather the result of a tension between forces driving toward verticality and others driving towards a horizontal structure.

Fine and Whitney describe this tension with what they call the "Double Helix Model." (Fine & Whitney, 1996; Fine, 1998) They provide, as one example, the computer industry over the last few decades.

From the late 1960's through the early 1980's, the computer industry was vertical. There were a number of players, but they were all vertically integrated. They provided all the key elements of their own computer systems, from the operating system and applications software to the base hardware, rather than supplying modules and bundles provided to them by third parties. The products and systems all exhibited integral architectures, with little or no interchangeability between parts from different suppliers. Each company provided all elements of the final system, and so had to maintain all of the capabilities required to provide each of those elements. IBM was the dominant player in this industry.

In the late 1970's, the Apple personal computer appeared. IBM chose to launch a competing product, and its PC division chose to break from the vertically structured tradition. They designed the IBM PC modularly, sourcing processors from Intel and the operating system from Microsoft. This decision was made for the sake of speed and cost, but it precipitated a major change in the industry. The PC industry quickly became horizontal, with different players staking out their claims on pieces of the supply chain, and with different players becoming dominant in different pieces of the architecture.

This same shift toward horizontal structure appears to be happening in cars and in aircraft. While some people might claim based on the PC story that all industries are driven toward horizontality, Fine and Whitney claim that the horizontal structure is no more stable than the vertical one. For example, even in the PC industry, there are suggestions that horizonal powerhouses Intel (processors) and Microsoft (operating system) are using their strength in their section of the supply chain to expand their sales vertically. Intel is building PC motherboards and incorporating video and sound processing into its products. Microsoft is increasing its sales of applications and network management software, is integrating Internet software into its operating system, and is providing multimedia content and delivery through that software.

The general form of the double helix model is illustrated in figure 3.1.

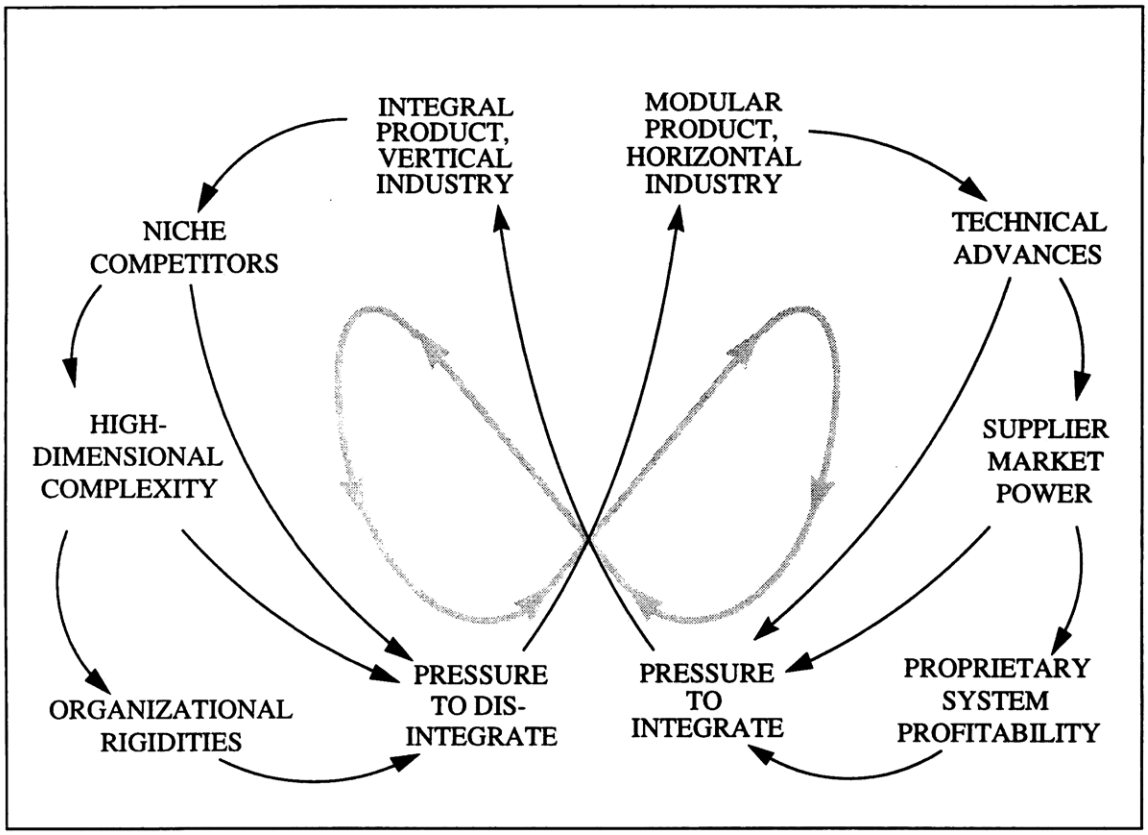

Figure 3.1: The Double Helix model (adapted from Fine and Whitney, 1996; Fine, 1998)

Whenever an industry is integral, it feels pressure to dis-integrate from three forces:

- The attempts of niche competitors to enter and take over pieces of the system that can reasonably be segmented out of the integral products
- The difficulty felt by market leaders in staying ahead on all of the many dimensions that create advantage in the product (for example, software and hardware and networks and operating systems)
- The organizational inertia that tends to settle on large, powerful companies.

All three of these contributed to the demise of IBM's vertical hold on the computer industry.

However, when (or once) an industry becomes horizontal or modular, there are pressures that drive it back toward a vertical structure with an integral product. Again, three forces drive the industry away from stability in a horizontal form:

- Each portion of the architecture can develop very stiff competition. Over time, winners can emerge and take over the majority of the market for a particular component. Those winners have a significant amount of market power, and they may try to parlay that power into more sales. The logical expansion of sales through market power is into the

neighboring segments vertically. This is what may be happening with Intel and Microsoft.

- Significant technical advances that do not fit into the dominant modular architecture may require an integral product architecture to be used at all.
- Proprietary systems are very attractive due to their profitability.

How does the Double Helix apply to HP's Patient Monitoring Division? The medical monitoring industry has been vertical for quite some time. However, HP began a transition by building systems on purchased hardware, just as IBM began a transition by selling its PC with purchased processors and operating systems. HP began using industry standard hardware to help manage the complexity of new systems. By purchasing hardware and operating systems, PMD could focus on developing monitoring solutions that integrate the best-of-class patient data analysis tools (some purchased from other vendors) and manage large amounts of patient data in a user-friendly way, while integrating smoothly into hospitals' data architectures. However, the double helix implies that the industry as a whole, not simply HP's products, will become more modular.

If HP does not adapt to the new emergent reality in the industry, HP will risk losing its leading position in the patient monitoring industry. IBM lost its leadership in PCs by remaining slow and dedicated to a vanishing world. PMD must prepare for a horizontal structure in the patient monitoring industry, with unbundled hardware, software, and services, or risk IBM's fate.

Fine (1998) goes on from the double helix to extend the definition of the supply chain to be the "capability chain". The capability chain focuses not on individual products or processes, which are all too transitory, but rather on the functions of the chain, such as "provide patient data to nurses and doctors in real time." He suggests that in industries that are becoming modular, the winners are those that control the dominant capabilities, either products or processes that can provide necessary functions that few others can perform; these are the capabilities that promise higher margins. For example, winners in the PC industry include Intel (controlling microprocessor design and manufacture) and Dell (uniquely capable of managing suppliers to provide quick turn-around with very low inventories.) The remainder of this chapter will argue that the dominant capabilities in the patient monitoring industry of the future will be robust software development and integration process development, once the hardware and integration execution become commodities.

Practically stated, PMD will eventually find itself in a modular industry, and it should be prepared to control the most important capabilities within it. But remaining a purely vertical

provider of an integrated product is not a viable option, even according to market-watchers within HP. Estimates within PMD vary as to exactly when customers will demand the ability to buy software only, but in interviews with HP marketing and development personnel the author did not get any estimates beyond 5 years. It is clear, however, that PMD will have to offer both bundled turnkey solutions and unbundled software in the future. This means that the customer will be loading and testing HP's software himself. And PMD risks being overtaken by a competitor (albeit only if the competitor has solid quality and functionality at a reasonable cost) if PMD takes too long to prepare itself to offer unbundled software.

Implications of Unbundling

The eventual unbundling of software from hardware will necessitate some changes within PMD. Because HP will not be part of the integration and installation processes in all cases, PMD must develop simplified processes and procedures for building the products, so that HP's specialized expertise is no longer required.

More importantly, HP must be sure that the final product works and performs adequately to ensure patient safety. In an unbundled environment, HP has less direct control over the integration of its products, so liability risk increases if processes are not performed properly. It will require a way to control that liability – carefully written contracts, tests for product quality that are "idiot-proof", easily executed and unambiguous as to whether or not they were passed successfully, and methods of proving that customers did or did not run the tests and observe their results properly.

2 Product vs. Process Competence

This section makes a distinction between product and process competence. Both are important, but each has unique implications for the supply chain structure. PMD must maintain some process and some product competencies for its patient information management tools, but only those that add unique value; others may be considered for outsourcing.

Product Competence

Product competence is in the design of the product itself, rather than in how it is made. One example of product competence is Coca-Cola. Although the process by which Coke's concentrate is made is kept secret, the "specialness" of the product is in the recipe, the design of the product. Many new high-tech products exhibit product competence only, because new

companies often have a great new technical design but must outsource production or at best cobble it together in-house.

Most shrink-wrapped software's unique advantages are in the product itself – because software is almost all design and almost no manufacture, software manufacturing processes usually have little to do with the value perceived in the end product by customers.

This is not to say that product competence does not involve a process. Many of HP's consumer products exhibit product competence, yet they do so because of internal processes that appropriately structure the product and supply chain. HP maintains a lead position in printers, for example, due not to manufacturing processes as much as to its ability to consistently introduce new, high-quality products before the market as a whole catches up to its current offering. Intel takes a similar strategy a step further, by following a rigorous process for bringing manufacturing up to high volumes quickly and with high yield.

For PMD, Product Competence = Hardware + Software Competence

The product competence in PMD's patient data management products is conceptually separable into hardware and software competence. The hardware must be reliable and fast. It must be able to handle the load placed on it by the software and users. The software must perform an ever-increasing variety of functions without fail. It must not overload the hardware, yet it must recognize when it has done so (or failed in another way) to avoid putting patients at risk.

By transitioning to industry standard hardware, PMD is eliminating the value in hardware competence. PMD's information management products require quality, but they are sold based on functionality. New data analysis algorithms and new features for users are the primary sales drivers of these products. That is why the software is the primary product competence while the hardware is becoming a commodity. This was not the case a couple of product generations back, but PMD made the decision that designing hardware was not the most efficient way to get functionality to the market. PC manufacturers are already designing and building high-performance hardware, so PMD is leveraging that investment by outsourcing or purchasing most of the design and assembly of its hardware.

However, right now hardware design control is a major activity within PMD for some hardware components. PMD performs homogeneous lot verification for some components in a kind of *ex-post* control; for other components it negotiates design freezes for its version of a standard component. In these cases PMD is really outsourcing the manufacture of special

components rather than buying off-the-shelf. This is because even though these components are standard product configurations, PMD imposes special design and process controls on its vendors. This kind of outsourcing is not intrinsically bad, but to a degree it locks PMD into staying with those suppliers in which it has made the design and process control investments. This makes flexible sourcing more difficult for PMD.

As long as the software is not separable from the hardware due to technical considerations, HP is investing in hardware control that adds no value from the customer's point of view. The homogeneous lot verification process is simply a check that components will perform adequately with HP's current product and process design. Value is only provided through the absence of a technical problem. That value is perceivable right now, because HP's competitors have the same technical problems. However, if one of HP's competitors resolves the issue, it could eliminate the cost of providing that value while HP would still be forced to pay to provide it.

Apart from technical (process) difficulties in implementing the product design, the software is the remaining product competence. It is where the functionality resides, and therefore where customer value is added. That said, increases in functionality will require increases in hardware performance. If the increase in technical requirements can be made slower than the industry-wide increase in hardware functionality, then the technical difficulties should decrease over time. Opinions are divided within PMD, and even within its R&D function, as to whether its products will require top-end hardware for the foreseeable future, but it is clear that PMD's engineers will gain experience with such hardware products that help improve its management of the technical issues.

Process competence

Process competence lies in a provider's execution capabilities, and the design of its demand fulfillment processes. For example, Dell's designs have little to do with its success. Rather Dell's unique processes to manage vendors and inventories, to customize customer interactions, and to deliver products with surprising speed, provide Dell with its special position in the PC market.

Most great companies succeed through a combination of product and process competence; they know what to make and what processes are the most important in providing it to customers. Coca-Cola shows process competence in addition to the product competence mentioned earlier. Its ability to manage its brand, and to ensure that a Coke is always available

when impulse strikes a customer, are powerful contributors to Coke's success. It further recognized that syrup production was the most profitable capability in providing its drink to customers, so it divested bottlers and focused primarily on that. While people differ on the extent of Coke's product competence, these process competencies are undeniable. Intel's process competencies include its ability to design new processors very quickly, to execute technical specifications that few others can match, and to ramp up chip manufacture faster than anyone else in the industry. These delivery process competencies, combined with Intel's brand management process competence, enable Intel to lead or even control its industry.

HP's process competence in patient data management tools lies in manufacturing, test, delivery, and installation processes. However, HP's unique (non-outsourcable) process skills lie in the development of these processes and in customer management. This is partially because these skills have been required of HP Medical for longer than any product or technology's life-cycle, but partially because they provide the greatest value in the capability chain.

As a leader in the medical products industry, HP Medical must have process development and control as a core competence. PMD's relationship with the FDA relies on that. And if we remove process control and customer order management processes from the picture, the remainder of the integration processes are non-core; they are also becoming commodity processes. This is not apparent today, however. There are two reasons why PMD's current hardware and software integration processes appear (misleadingly) to have core competency elements:

- The software is not always robust enough to work on commodity hardware. Right now in order for PMD to offer some products at all, PMD must do the integration and test the hardware, to ensure that the product will work reliably. If the software design becomes somewhat more robust to variations in hardware components, and PMD develops software tests that are performable by other partners, then hardware integration and testing will clearly be commodity.
- Within the integration and test processes, process control cannot currently be separated from the process itself. The processes are not yet stable enough and simple enough for them to be viewed as decomposable into the management of the process and the execution of the process. Because process management must remain a PMD competence, the process execution must remain within the organization until it can be separated from customer and process management.

Because of the delivery processes currently performed by HP will in the future be performed by customers or by third-party providers, either within or outside HP Medical, PMD does not have complete control over the execution of the processes it designs. Therefore, they must be more robust in order to provide similar value. This implies an increase in cost for the same product, but it is not a cost that customers will want to pay. Instead, HP must depend on its ability to design robust implementation processes whose increase in cost is less than the perceived increased value customers see in the unbundled software product. This perceived value increase is likely to be small, particularly if multiple competitors are offering unbundled software products; thus low-cost HP process development capability is crucial to its leadership position in the patient data management market.

3 Competitive Advantage in the Unbundled Product Market

The primary new feature of the unbundled product market for HP is the fact that with an unbundled product, PMD will not be executing many of the delivery processes. They will instead be performed by customers or by third-party providers. HP is entering a new market type; or, rather, is changing its own market to a new type. It will be providing software independent of hardware. Independent software is a difficult market in which to make money. HP must maximize the value it provides to customers, through its structuring of the capability chain, or a competitor may try to steal its position.

Selection of Core Competencies

Common wisdom today says that companies should retain competencies that are integral to their value proposition, while where possible outsourcing the others. Quinn & Hilmer (1994) describe four ways in which this approach maximizes firms' return on resource investment:

- It concentrates investments and energy on what the enterprise does best, while avoiding investments in areas that do not provide such high returns.
- By leading the industry in certain capabilities, it builds barriers against competitors that (now and in the future) try to expand into the enterprise's market space.
- It fully utilizes external suppliers' investments, innovations, and special capabilities, that would be expensive or even impossible to duplicate internally.
- It decreases risk, increases speed, reduces fixed investment, and allows better responsiveness to customer needs.

Although there are concerns to be weighed against these advantages, all of these advantages do apply to PMD. HP has limited resources available for product development and management, needs to control its fixed investment and respond to customer needs, is working to protect its market position by leveraging hardware developments and other supplier capabilities that it chooses not to develop internally. Exhibit 1 describes the author's supply chain analysis that showed it to be infeasible for PMD to develop many of the capabilities that it is already purchasing, and showed that outsourcing further might have cost advantages.

Venkatesan (1992) further drives home the idea that management must consider the value of focusing on only a few skills when deciding how to allocate attention, based on interviews with hundreds of managers:

> "Few managers seemed to appreciate the true opportunity costs of investment in such intangible resources as management attention and engineering talent. They failed to realize that their 'we can do it all' mentality was, in effect, depleting the limited energy their people had for changing manufacturing routines, let alone strategic thinking."

The effort spent on managing whole sections of the capability chain in which the firm does not excel is effort not spent enhancing those competencies in which the firm is a leader.

However, firms must consider the possibility of losing control of even their strengths if they rely too much on outsourcing. The selection of the competencies to maintain can determine the strength of the company relative to its suppliers.

Dependence on Capacity and Knowledge

Any time a manufacturer outsources, it risks becoming dependent on its supplier. However, there is a significant distinction between dependence for product knowledge and dependence merely for production capacity. Fine and Whitney (1996) expand on a concept they credit to Geoffrey Parker, which makes this distinction clear. *Dependence for capacity* results when a company could (and may currently) make the product in question in house, but for reasons of time, money, space, or management attention chooses to use a supplier to extend its capacity. *Dependence for knowledge* results from a case where a company lacks the skill or knowledge to provide a necessary component, and therefore seeks an outside supplier.

It would be strange for a company to be dependent for knowledge while independent for capacity. So the question raised is whether a company that outsources a process or component becomes dependent on its supplier for knowledge and capacity, or merely for capacity alone. The ramifications of dependence themselves depend on the architecture of the product being outsourced. Modular architectures are divisible, so that dependence of either sort is contained within a single component or process. Integral architectures raise the stakes substantially, so that

suppliers are more able to expand their influence into other aspects of the product. Figure 3.2 shows Fine and Whitney's concerns.

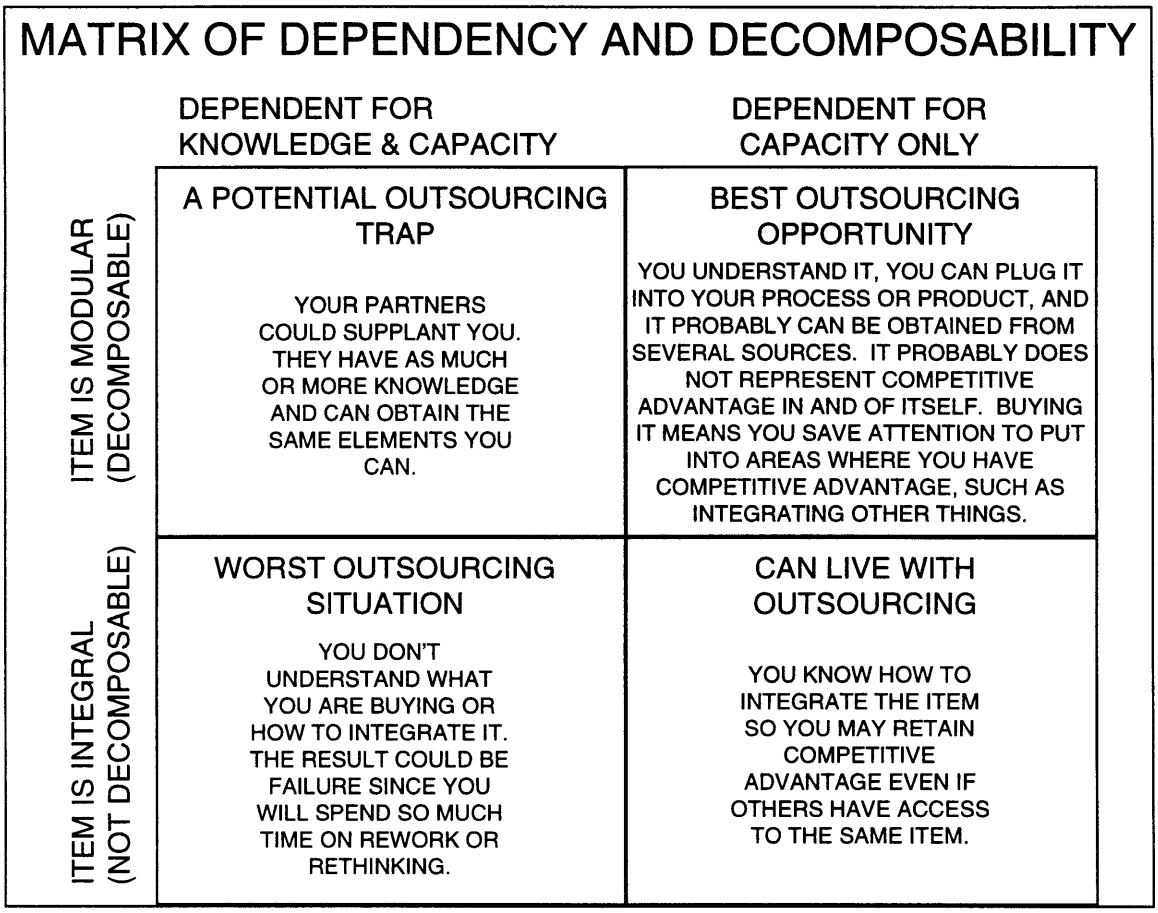

Figure 3.2: The Matrix of Organizational Dependency and Product Decomposability (Fine/Whitney, 1996)

If we apply this concept to HP, we immediately see a concern with the outsourcing that PMD has already undertaken. PMD has voluntarily become dependent for hardware capacity. Furthermore, PMD is at least somewhat dependent for knowledge for their industry standard hardware. While PMD's engineers understand hardware very well, they choose not to maintain a deep skill-set in the computational heart of the hardware they buy; that is, they could not themselves design the hardware they use. According to Fine & Whitney's general model, this is a concern. If the product is integral, they would be in the worst outsourcing situation; if it is modular, they still would be in a potential trap.

However, as PMD has decided to build products with industry-standard hardware, it has also driven the hardware portion of the product toward modularity. It is working to make the hardware entirely interchangeable within a limited set of product specifications. PMD is moving out of the lower left quadrant up to the upper left as it reduces the dependence of its software on its hardware.

Note that this points toward the necessity of further disintegration. Fine and Whitney's general model has predicted the issues that PMD faces with the robustness of its software. The clear imperative is for PMD to make the product truly modular to get out of the "worst possible outsourcing situation". And although the general model says that the upper left quadrant is not much better, in PMD's case it can be considered a safe haven. Safety comes through being a small part of a big commodity market.

Fine (1998) adds the number of suppliers to dependence and modularity in the matrix. His point is that dependence on an industry is less dangerous than dependence on a single supplier. Hardware is becoming a commodity industry, with many players offering substantially the same product. As long as the software works on many hardware products, PMD is less susceptible to holdup because of its ability to change suppliers. This makes the robustness of software to hardware variation a strategic sourcing issue, beyond its current cost implications.

The raw computing hardware market is very large. However, PMD and the entire medical monitoring industry is using only a very small portion of that hardware. It would be very surprising for an industry standard hardware manufacturer to try to move into the medical market. The other competencies are simply too expensive to develop. So as long as PMD creates a modular architecture for its products, and is merely outsourcing hardware manufacture, it can consider itself safe despite its dependence for hardware knowledge. This does not, however, reduce the competitive risks created by a modular product structure; it is just that the risks are from medical monitoring competitors rather than hardware manufacturers.

Hardware manufacture, software development, integration, delivery, and customer management are very different links in the capability chain. If HP becomes dependent for knowledge on a critical piece of the capability chain, Fine and Whitney's model implies that it can expect to lose its position in the market as the owner of the critical piece exercises its newfound strength. PMD already outsources hardware manufacture and the risk is controlled. If PMD maintains control over software development and customer management, it can control the risks in outsourcing integration and delivery.

However, if HP outsources its software development indiscriminately, then it is reasonable to expect that eventually the designer of the critical software components will go into the medical information management business for himself. Fine gives some examples of where this has happened in the past or is happening currently, such as PCs (IBM, Microsoft, and "Intel Inside") and bicycles (Shimano taking the lead in the industry through controlling componentry).

Hardware Handling

Once we decide that software development is a core capability for PMD, we can examine the physical supply chain for hardware. Figure 3.3 shows one way to look at the options PMD faces for sourcing products.

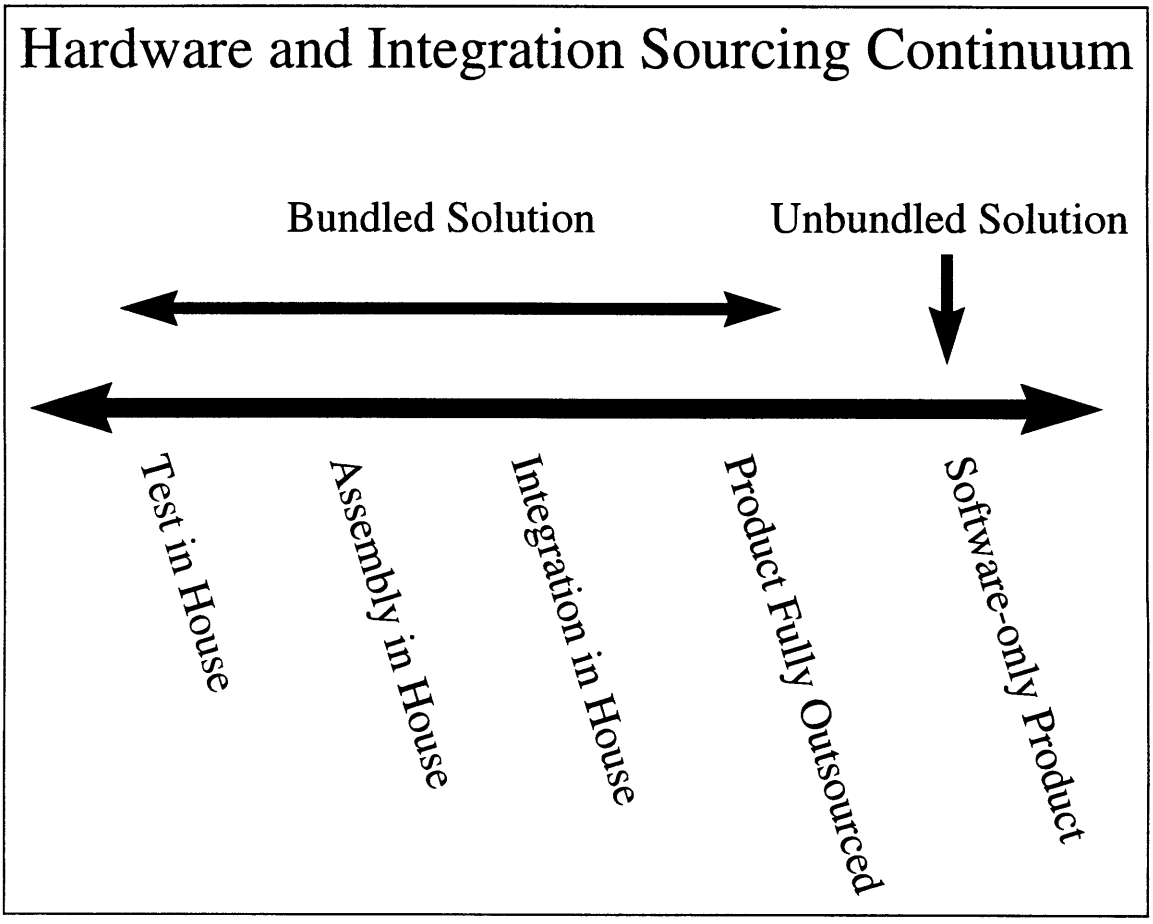

Figure 3.3: Hardware and Integration Sourcing Continuum

PMD's hardware sourcing must fall in a range between producing everything in-house and performing every process outside. As more processes are performed outside, PMD's work becomes less production and more control. The software-only part of an unbundled product solution is one step beyond fully outsourcing assembly, integration and test. It shifts process execution out of PMD and beyond a third-party provider, all the way onto the customer himself.

HP currently maintains competence throughout its vertical supply chain, with the exception of the base hardware manufacture. Some processes involve more special value than others. In general terms, the value will increase as one moves to the right in the sourcing continuum. This is due to two particulars of the product we are addressing:

- Functionality is primarily what contributes to customer perceptions of value. Functionality is primarily defined by software, provided the hardware does not limit the software's execution.
- The closer we get to the customer within a medical product supply chain, the more important it is to control the quality of the product, and the more responsibility to the customer (and the FDA) we take on. This value is provided in a negative way, in that it is an absence of problems; as we move to the right in the sourcing continuum, it becomes more imperative and more difficult to assure the absence of problems.

There is a tension within HP over the value in the absence of problems. Development and manufacturing engineers clearly recognize the costs of ensuring an absence of product problems to the customer. They also recognize that those costs will increase if we move to outsource hardware handling, and probably increase further if we allow customers to integrate the product themselves. However, marketing and PMD management appear to have faith that those same engineers can control those costs; further, they believe that there will be significant value provided by an unbundled solution. These two seemingly conflicting ideas within PMD are resolved if outsourcing is considered to be more a step toward unbundling the product than it is a short-term cost saving technique. If HP chooses to limit the capabilities that it maintains, the easiest to shift outside are those to the left of the hardware and integration sourcing continuum. And because eventually PMD must offer the unbundled solution to some customers, it should minimize the costs in managing the hardware handling processes outside HP.

The Need to Focus

There are two major reasons why HP must focus on only the capabilities that add long-term special value to HP's products:

- The significant change in the patient information management industry that PMD has started will require as much managerial and strategic energy as possible be devoted to maintaining a market-leader role.
- Eventually obsolete capabilities become liabilities, and deeply-ingrained competencies can be difficult to change.

Leonard-Barton (1992) supports the positive aspects of focus on a limited set of important core capabilities. However, she also cautions that core capabilities can become "rigidities" that limit the enterprise's ability to adapt to a changing world. She describes these rigidities along four dimensions, but the two that are most relevant to PMD's situation are the dimensions of technical systems and management systems. If HP does not successfully retain the right competencies, it runs the risk of establishing rigidities that make it vulnerable to new competition and market changes.

If PMD retains all of its hardware sourcing capabilities in house, it will have a large investment in technical skills on the hardware platform currently in use. There will be a number of technical applications built for software load and integration that rely on the current generation of components. As the best architecture for the product changes, HP may be reluctant to scrap that investment to stay on the cutting edge.

PMD also has management structures, metrics, and processes established to manage a hardware handling business. These systems will not serve PMD as well when it must ship unbundled, software-only products. Customer-oriented metrics will clearly shift toward ease of installation and use, and less toward delivered cost, for example. If PMD defines itself primarily based on its hardware handling capabilities, it may find itself in a software world, without the nimbleness it needs to address customer needs.

Implications for PMD

Because PMD needs to focus on only the most important capabilities for the future, and because the smallest future value will lie in hardware handling, PMD should retain control over the software product competence (including competence in maximizing robustness) and the process development, while outsourcing hardware assembly and integration. This will allow PMD to focus resources where value will be most concentrated.

However, it could reasonably be argued (although in interviews with personnel across PMD it was never said outright) that PMD has a significant lead over its competitors in product and process technology; perhaps PMD should leave the product and market intact while it is still making strong margins on its products. After all, the market moves fairly slowly, and PMD should have time to get to the next product paradigm before it is forced to. Why should PMD hasten the demise of a profitable structure?

The response to this argument depends on one's view of the pace of change in medical monitoring. If one believes that product life cycles will continue to be up to ten years, then the

only response is one of long-term strategy and an appeal to PMD's vision, which would suggest that advancing the industry and the quality of patient monitoring in general is good independent of short-term profits.

Many others believe, however, that the move to industry standard hardware will ("through osmosis" as one HP engineer put it) increase the pace of change in patient data management products. In this environment, PMD will only stay on top of the industry by being first to market with fully unbundled solutions.

Furthermore, HP should begin the process well before the market demands unbundled solutions. The transition will take time, particularly if PMD follows a conservative transition plan. Also, there is a strong synergy between readiness for outsourcing and readiness for unbundling software and hardware.

HP must eliminate the dependence of its software on its hardware. It must eliminate the requirement for homogeneous lot verification; hardware restrictions like that will frustrate and worry customers. This will require substantial effort directed toward making the software substantially more robust to hardware variation, and eliminating or fully controlling for the barriers to real-time performance. HP must also develop implementation processes that can be performed by any partner. In the extreme case of a software-only product, that partner will be a customer, over whom HP will have very limited control.

Note that these technical requirements to offer unbundled solutions are the same as those to outsource the hardware handling for a bundled solution. By moving to outsource hardware handling, PMD can develop the competencies it needs for the future world that includes software-only products. Outsourcing can be considered to include the first steps toward unbundling the software products from their hardware.

Leonard-Barton provides a model for the development of core competencies. Projects that leverage the core competencies of the enterprise are more likely to succeed; in turn, those projects increase the strength of those competencies. This reinforcing cycle helps develop very strong competencies, and increase focus. HP is in a position where it needs to grow its robust software development and installation process development competencies.

By taking on a project to outsource hardware handling, PMD can exercise and develop those important skills before it is forced to demonstrate them directly to customers. PMD can jump-start the reinforcing loop of competency development. With the head start PMD develops over its competition, it can leverage commodity hardware (for knowledge and capacity) and mass integration services (for capacity only) to cut costs and increase the pressure on its competition.

Given that PMD will offer unbundled software to some of its customers, it must offer the best perceived value per process to all of its customers. When customers ask PMD to perform hardware sourcing and integration, it must be provided according to a particular value strategy. For any particular level of functionality and service, it must be provided at minimum cost. By focusing on robust software development and integration processes, while relying on outside suppliers for hardware handling, PMD can maintain its market leadership and deliver at the lowest cost possible.

Chapter Four : The Transition

Once PMD has made a decision to outsource its hardware handling processes, it opens up a new set of questions. This chapter looks practically at the sub-strategies that HP should consider when developing a transition plan. Multiple dimensions of the problem need to be considered together.

1 Moving Products Together vs. Separately

A first consideration is how to group products for the transition to an outside production process. PMD has a variety of information management software products, already at various levels along the hardware outsourcing continuum. The products can be transitioned individually, grouped by current level of outsourcing or by technology family, or all of PMD's patient data management products can be transitioned at once.

The factors that point toward larger groupings of products are primarily organizational:

- A single implementation will probably take less time than a phased transition.
- The fewer separate transitions that must be managed, the less aggregate organizational disruption is likely to occur. That is, the whole is smaller than the sum of the parts, because each transition brings some disturbance which must be repeated for each transition.
- Costs incurred in transition will be smaller, due to reductions in fixed (repeated) transition costs, scale economies at the outsourcing partner, and reduction in interim process management.

A 1997 supply chain cost analysis project conducted by the author showed that even if process costs are reduced through outsourcing, costs will often increase if the process is outsourced for too small a product group. This is because the support costs have a fixed component, and are therefore non-linear with respect to volume. Small volumes must bear the burden of all of the support costs, driving up unit costs. If PMD chooses to outsource products in very small groups, then throughout the transition phases there will be many distinct processes to support for different products, each expensive due to small unit volume.

The above notwithstanding, there are two primary reasons to suggest that PMD avoid large groupings of products for the transition. The first is organizational – products are at different stages of readiness for the transition. The second is risk, which is difficult for a medical manufacturer to voluntarily take on.

Some of PMD's patient data management products are very ready for outsourcing, while others will require a significant amount of development effort before they can be successfully transitioned to outside integration. This makes a single group transition more difficult. To change the products together, PMD would have to pick an ending structure and move them all from wherever they are to that point simultaneously. The timing of that transition will be much later than is necessary for the products that are already very modular and partially outsourced. Despite the increased support costs, PMD may be able to gain a significant head start if it moves the easy products now.

Also, some products will entail risks to outsource, and managing those disparate risks could make a single-group implementation take a very long time. There is a significant level of risk associated with outsourcing medical device manufacturing. In particular, PMD is still learning how to work with software products working on industry standard hardware components. Some products are very sensitive to hardware variation and process controls. Significant changes to the supply chain for these products will create risks that shipments will be held up, or that product quality may suffer (which means that shipment will stop, because PMD is unwilling to ship under-quality product). The financial risk is particularly great for products that are often tied to large amounts of other PMD revenue. Moving lower-risk products first will enable PMD to gain confidence and stabilize the destination supply chain before moving higher-risk products.

A potential compromise might be to transition HP's products in two large groups, maintaining as much scale economy as possible, while recognizing that some products will be much easier to transition than others.

2 Pace of Transition

In addition to how to group products, PMD must consider the rate of change. Three high-level alternatives will be identifiable as *immediate, phased,* and *held.*

Immediate

PMD could begin to establish the full outsourcing relationship immediately. This is a form of "shock therapy". It is certainly going to produce the fastest results, but it also adds to the risk of stopping shipment temporarily. If things go badly and yet shipments do not stop, then there will be a risk of shipping bad products, which is unacceptable to PMD.

Because a large portion of HP's patient monitoring sales are tied to the ability to ship patient data management products, the risk of stopping shipment for even a small group of products carries a significant financial and customer service penalty. HP is probably not capable of accepting this level of risk.

However, the risk of this approach is likely not as great as it appears at first glance. PMD has skills in developing comprehensive contingency plans, and can show a lot of ingenuity and energy when confronted with a problem. Provided the organization is committed to making the relationship work, an immediate transition is not out of the question.

Phased

Here HP would identify the eventual partners for the full outsourcing relationship. However, it would transfer processes to the partners only a little at a time, as the partners and processes are ready. For example, PMD might ask the partners to inventory hardware and perform initial hardware integration, but then ship the products to HP for software load, test, and delivery to customers. In this case PMD might even maintain an extra inventory of integrated hardware as a buffer to decrease supplier performance risk. Alternately, PMD might begin by having contractors manage parts of the processes within HP, then transfer those functions to the partner's facility after the processes are running smoothly between HP and the other organization.

This would enable PMD to iron out the information and order management issues before any product or process issues arise. Risk is dramatically reduced. Another division of HP is using this more conservative approach to outsource similarly integrated products. The implementation is in its earlier stages, but all indications are that things are going smoothly.

The reduction in risk is purchased at a cost. The increased cost in this approach is threefold:

- It takes longer to get to the eventual supply chain. Assuming that the eventual supply chain is the most efficient, delays can be costly.
- During the transition, some of the process allocations between partners are much less efficient. If outsourcing one process saves very little in process cost while greatly increasing support cost, PMD will be producing at a higher cost than no outsourcing at all.
- Support processes are established for interim steps which require rework or re-creation for later steps. The multiple steps require much more process development, incurring delays and costs.

If HP moves with a phased approach, it should expect costs to rise rather than fall during the transition phases. Costs will be back in line when the transition is complete, but this could take some time.

Held

PMD can take an even more risk-averse approach. It could implement nothing until everything is ready, with the expectation that an immediate transition will be made when all of the preparation is complete. By preparing the products and structures fully for the transition before it is made, HP could minimize the risks in the transition.

The problem with this approach is that there will always be risks in a supply chain transition such as this. The immediate transition can always experience problems, and even the best engineers cannot plan for absolutely everything. Therefore, there will always be some level of risk. Clearly preparation will reduce those risks, but the concept of waiting for a risk-free transition encourages inertia. So there is a new risk with this approach that nothing will ever be fully ready, and no change will ever occur.

Figure 4.1 illustrates the options, and how PMD might currently map onto them.

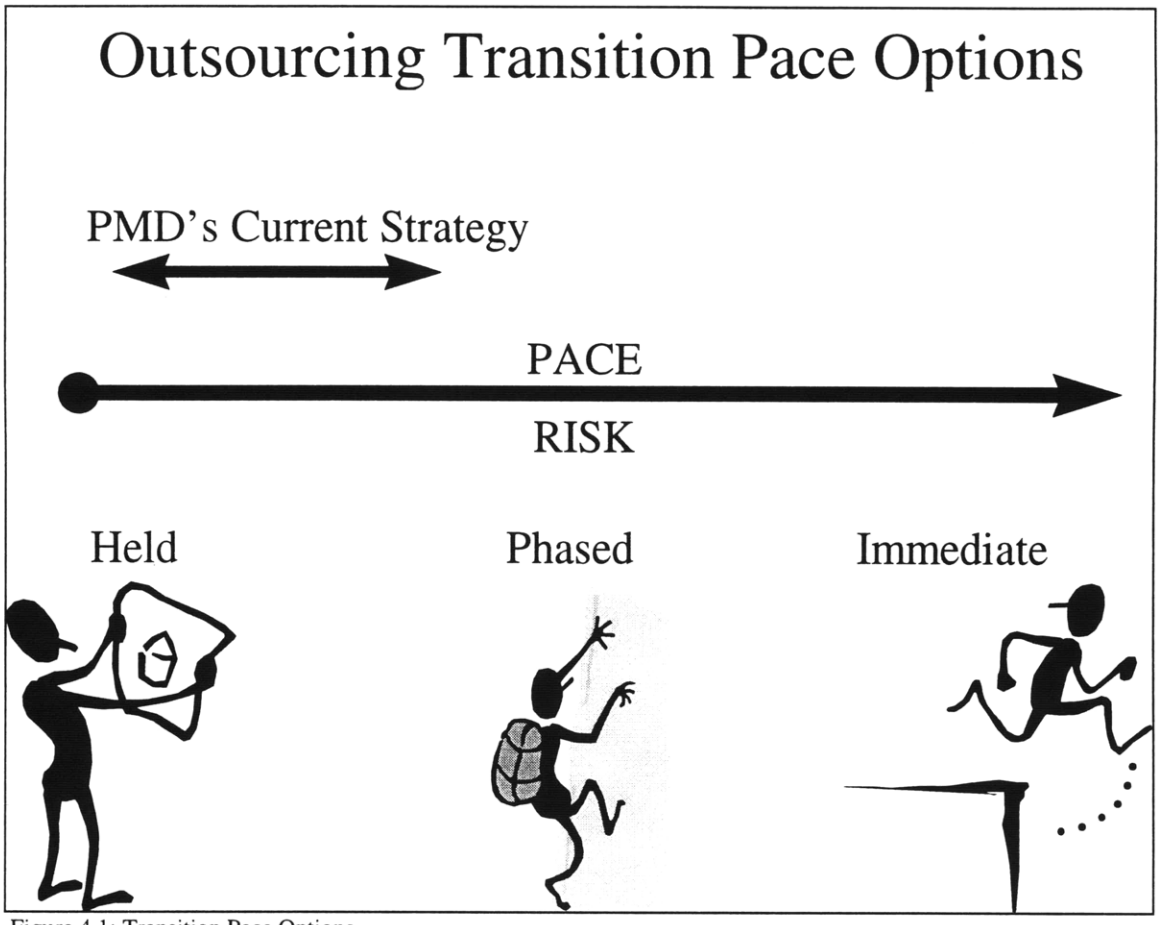

Figure 4.1: Transition Pace Options

3 Current Operating Paradigm

PMD is working to bring structure to a previously unstructured strategy. PMD's management wants to do whatever is best for the products and the division overall. It wants a unified high-level strategy, in that all products are considered together, whether the best decision is to move them as a single group or in stages.

The emergent operational strategy at PMD has been to treat products separately, based on very practical considerations. For example, some of HP's patient data management products are already very modular, and they are also very small in volume. These products are partially outsourced now, and becoming more so over time. PMD has been making investments in internal infrastructure for other products, planning to keep them in house due to their technical complexities. The lack of coordination is not endemic; if PMD's management lays out a coordinated, scheduled plan to handle all products, operations will be able to follow that course.

Along the pace dimension, HP is currently holding and preparing for most of the products in the scope of this thesis. There is a limited of early stage phased work, but these

products are currently limited technically in how far they can transition. For example, if HP cannot be sure that any hardware of a particular type will work properly with a software product, it is extremely difficult to ask a partner to manage the hardware inventory.

Without a specific coordinated plan, practical considerations suggest that any individual decision will be to hold implementation until outsourcing is less expensive and less risky. This was in evidence in interviews and sourcing decision processes witnessed by the author during the 1997 supply chain cost modeling project. At the level of analysis for most sourcing decisions in the absence of a division-wide plan, novel sourcing approaches suffer from three problems:

- Cost advantages will not be substantial, because all of the processes that are required for the product under consideration in house would still remain in house for other products if one product is outsourced.
- Without a history of learning or an organizational drive to try a new approach, the risk perceived by decision makers will not be worth the perceived long-term advantages. There can be general agreement that new sourcing approaches are required, but no individual decision maker wants to take on the risk.
- PMD's customer focus creates a drive to bring new functionality to market as fast as possible; making a change to the supply chain is (quite reasonably) perceived to increase time-to-market for the first products to try it.

All of these concerns can be addressed in a unified PMD sourcing strategy. Leaders of individual sourcing efforts will be more comfortable trying a new approach if they are able to relate any cost, risk, or timing problems to the division-wide sourcing initiative. The personal risk will be significantly reduced.

Moreover, if HP adopts a specific plan to outsource products, there will be internal pressure to solve all of the technical problems that currently keep the organization holding. A plan with a deadline may create the "burning platform" that HP needs to overcome inertia. Until HP overcomes that inertia, it is leaving potential savings and strategic advantage on the table. More importantly, a lack of direction relieves pressure on the development of unbundled software solutions, which could leave PMD at a greater risk to competitors.

Chapter Five : Recommendation

The recommendation follows directly from earlier analysis – PMD must work to outsource its hardware and software integration processes, while maintaining control of customer relationships and software development. This chapter details a recommended approach to outsourcing, making choices about the tradeoffs described in Chapter Four.

Because there is no single right answer to how HP should address sourcing for its patient data management products, we must also consider the costs and benefits of the recommended approach. The recommendations also include some practical considerations regarding changes PMD needs to make as well as attributes of an ideal outsourcing partner. The chapter and thesis will close with a potential task list and timeline for PMD to implement the recommendation.

1 Approach

To protect its current market advantage and position itself for future market leadership, PMD should have a goal of outsourcing hardware integration, software load and test, and delivery of its patient data management products. A clear schedule is required to coordinate multiple efforts throughout the division, and top-down management support is essential.

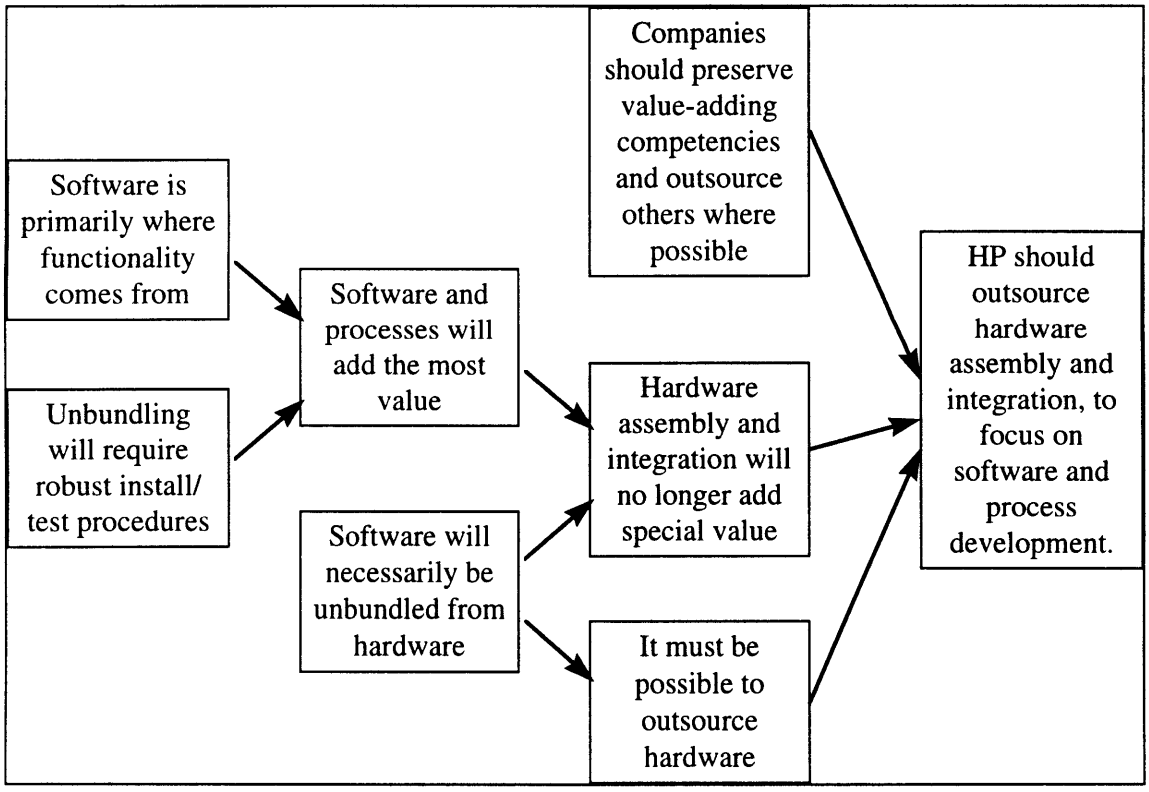

Figure 5.1: Logical Structure of Analysis and Recommendation

Within the schedule, PMD should segregate its patient data management products into two groups, and begin a phased transition to outsource the less technically restrictive group, while simultaneously focusing technical development on reducing the reservations with the more restrictive group. Once both initial efforts are largely complete, PMD can quickly phase the second group of products outside.

Product Grouping

By segregating products, PMD can begin to gain experience in outsourcing without incurring the risks that keep it from moving faster now. Call the groups "A" and "B", but consider the two groups A = "easier-to-outsource", and B = "difficult-to-outsource".

Group A products are simply those that have no difficulties. Several things may lead PMD to consider a product difficult:

- Manufacturing the system is an extremely intricate process, such that a partner might take a long time to become competent, or good medical manufacturing practices may be hard to verify.
- The system requires a large amount of manufacturing process control, such as homogeneous lot verification.
- The system is typically at the heart of very large PMD customer orders, so that an interruption in shipment would hold up a large amount of PMD revenue.

Group A products are likely already close to being unbundled, and are generally hardware-independent. Group B products are considered too risky to move quickly. PMD can gain outsourcing experience quickly while making it technically feasible to begin outsourcing its more difficult products.

Phased Implementation

The implementation approach is broken into two major phases – move group A, then move group B. However, while PMD is moving group A, it must also be advancing its technology and processes to the point that group B is no longer so difficult. When group A is moved and group B is outsourceable, PMD should move group B relatively quickly, to maximize the organizational gains from outsourcing. Figure 5.2 illustrates the recommended transition plan.

To move group A specifically, PMD will best be served by a phased implementation. To maintain solid control over medical device manufacturing processes, PMD must phase the

transition, whether process by process or by maintaining capacity within PMD while establishing the outsourced capacity. PMD's risk-averse nature would be at odds with any more aggressive approach. During the phased implementation for group A, HP will be learning about the processes and relationships necessary for successful outsourcing, and experiencing some of the pitfalls along the way, in a lower-risk implementation.

Some group A products will include peripherals and add-ons to group B systems. To the extent that these peripherals are modular and separate from the larger systems, they can be outsourced very quickly. Hardware that does not require integration as part of the manufacturing process can be merged with systems immediately prior to (or during) shipment to the customer. Such hardware should be easy to transfer to a partner for management and can start the phased implementation.

Concurrent with the transfer of group A products to outside production and inventory management, PMD must be working to remove the technical barriers to outsourcing the remaining (group B) products. Holding back on difficult products cannot be considered a reprieve for the effort overall, or PMD will find itself with partial outsourcing that achieves little cost benefit and very little of the strategic gains that it should be working toward.

If it takes two to three years to transition group A products to complete outside hardware handling and software integration, it should take approximately as long to prepare group B products to begin the same transition. The skill level of HP's development engineers is high enough that if modularity is assigned a top priority, with a deadline built into the schedule, it is very reasonable to assume that PMD's patient data management products could be fully modular in two years, with no significant barriers to outsourcing all of these products.

Once the group B products are modular, and HP has accumulated learnings from outsourcing the group A products, it should be able to implement an accelerated phased transition for the group B products, taking perhaps half as long as the group A transition. Although the group B products are important and risky, the implementation will have the advantage of all of the development effort spent on robustness, as well as the all-important experience of having done it all before.

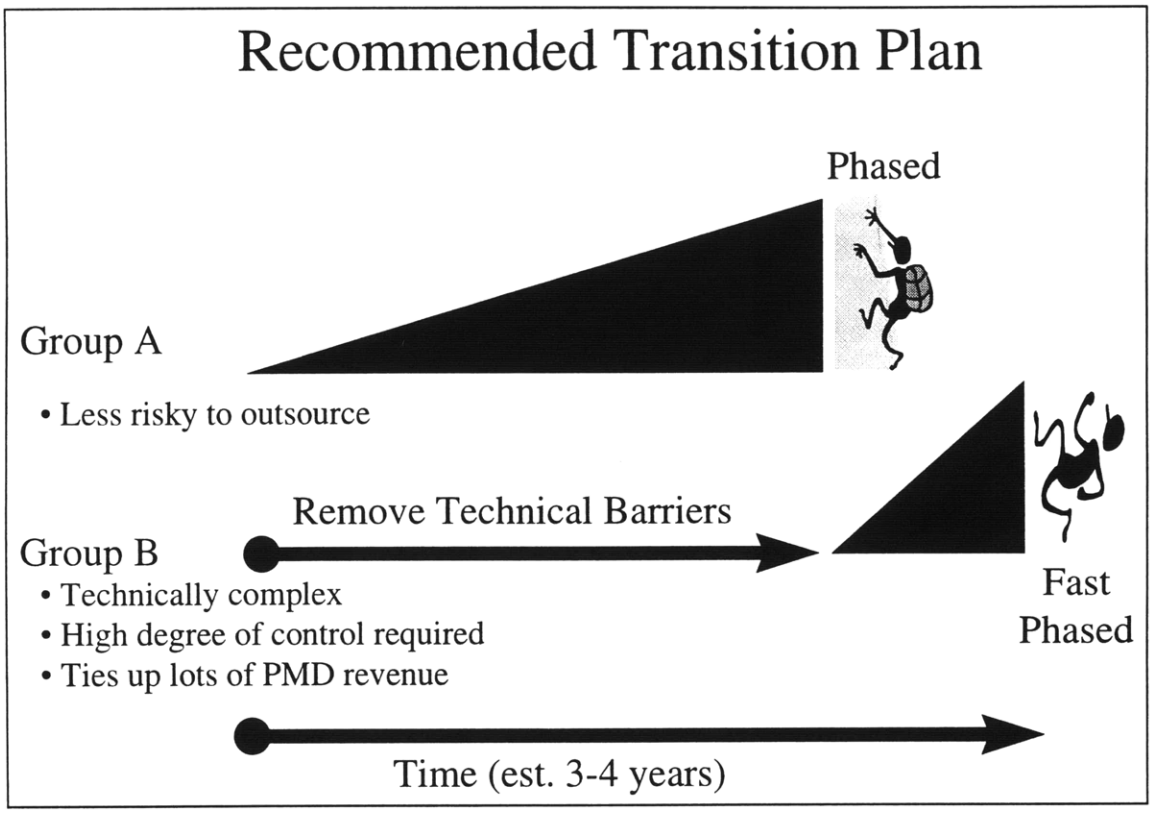

Figure 5.2: Recommended Transition Plan Illustration

2 Cost/Benefit

It must first be noted that the primary benefit of the approach, and in outsourcing hardware handling in general, is not the labor savings that will result. Rather, the primary benefit is in the process itself, in the cleaning and organization of products and processes that HP must undertake to accommodate the outsourcing. The direct cost savings are not entirely clear, but they are not likely to make a huge impact in HP's bottom line. However, the strategic leap to new market structures and the management focus that outsourcing allow may make all the difference in PMD's long term profitability.

Timing

The total time to complete the recommended transition will be substantial compared to a single-group implementation or one that is less phased. Each sub-project and phase will take time, which gives PMD's competition opportunities to catch up. There are two reasons why the recommendation takes so long – HP has a good lead over its competitors, and HP shouldn't expect to move any faster.

According to sources both internal and external to PMD (such as the trade press) HP's patient data management products are significantly ahead of the rest of the patient monitoring market. PMD's new product announcements are consistently breaking new ground in terms of functionality and use of industry standard hardware. As long as PMD does not stand idle for an extended period of time, it can take the time it needs to do a comprehensive, controlled implementation. Strong competitive pressures are some time away.

Of greater importance is the fact that the more relaxed timing will contribute to the project's chances of success. HP's careful nature with respect to medical device manufacturing will not support a project with a more aggressive timeline. To see this we can refer back to Leonard-Barton (1992), introduced in Chapter 3.

Leonard-Barton's work on core competencies and core rigidities considered a number of development and improvement projects undertaken by companies. She found that projects that are not aligned with the organizations' core competencies are less likely to succeed. HP Medical has long held competencies in maintaining careful, controlled processes that guarantee high-quality medical devices. Any project that does not support that competency will find resistance to the speed of change, a core rigidity.

The new sourcing implementation is aligned with the future direction of PMD, but it also is trying to shift some of the competencies currently in evidence. It supports competence in software design and installation processes, but works to change the notion that HP must have complete physical control over the product to ensure a quality result. This partial alignment with existing competencies is the strength and weakness of the project. As such, it requires that HP take the implementation at a reasonable pace, and that PMD's management show unqualified support for the goals of the implementation.

Difficulty and Risk

No implementation can be undertaken without some level of risk. The only apparently riskless choice for PMD is complete inaction, and that choice would eventually prove to be the most dangerous. The primary risks in the recommended approach are in delays. The timeframe is already stretched; a lack of urgency could reduce pressure on the development tasks required to make the group B products modular and outsourceable. However, this risk can be mitigated by a fixed schedule. Also, it is not as severe a risk as that of problems arising in a faster implementation. The most threatening risks, those of product shortages or quality issues, are better controlled by the careful implementation.

By beginning to move some products now, HP will have some success quickly, helping make later transitions easier. Frequently organizations that recognize the importance of a major change to operations have problems just getting the process started. The recommended approach makes it easy to begin the process, and to continue the process once under way. Provided HP keeps abreast of market changes and does not allow the implementation to take longer than its strategic lead will allow, the approach minimizes failure risk.

Cost

Some process and support costs will increase during the transition period. The two large product groupings alone would necessitate duplication of support processes within and outside HP. The phased implementations for each group will force PMD to develop interim processes that will be in use for only a short time. Some of the interim steps may have only a small number of products processed in certain ways, which may not provide an efficient scale.

The cost increases will be only temporary, and will be clearly understood to be an interim cost as HP transitions to an eventual supply chain structure that will cost less over the long term, both directly and in terms of management focus. The costs of the implementation can be viewed as an investment in long-term market management and profitability.

3 Preconditions

There are a number of changes that PMD must make if it hopes to be successful implementing the recommended approach to its supply chain. They are primarily organizational; the division must structure itself around future competencies. To the extent that the preconditions are technical, they require that the organization set these technical issues as priorities, and measure people accordingly.

Technical Issues

PMD's development efforts must focus on resolving the technical barriers to outsourcing. Development tends to address marketing concerns before manufacturing concerns. This is good policy in the short term. However PMD is facing an important (though not yet urgent) task – that of providing unbundled software solutions within the next few years. Manufacturing challenges will become very urgent if a competitor launches a "shrink-wrapped" off-the-shelf patient monitoring solution, while PMD is still adding new functionality to software that is tied to complicated manufacturing handling of hardware. Working to outsource hardware handling is a practical step toward that unbundled solution.

There are several technical barriers that must be addressed:

- PMD must continue to standardize and to reduce the number of different operating systems, hardware platforms, and network standards used in its products. This will keep the hardware inventory management task from being needlessly complicated for a supplier or for HP.
- Software products must be robust to the hardware they run on. Different brands and lots of hardware should all be expected to work properly with PMD's software, provided it all meets clear specifications. HP must also continue to build its skills in writing clear desk-specifications for hardware capabilities.
- Software installation processes must be made consistent, unambiguous, and simple. Although there is no reason why a third-party integrator shouldn't be able to follow more complicated procedures, HP will cut costs and risks by making the software easy to install, and hard to install improperly. Simpler installation procedures will enable HP to spend less effort on ensuring that the processes are being followed properly, making outsourcing more effective. Moreover, when the day comes that HP is trusting the customer to install his own software, fool-proof processes are a must.

Eventually PMD's software products must be able to investigate the hardware on which they are loaded, to ensure that the capabilities of the hardware are adequate for complete, safe software functioning. Until software is being installed directly by the customer this is not necessary, but installation and testing processes will be much simpler if this capability is designed into the software earlier.

Organizational Issues

There are several less technical changes that HP must make for an outsourcing implementation to be successful. Manufacturing and customer management processes must be cleaned up, and PMD's vision must be clearly articulated in association with its sourcing strategy.

PMD's processes and process controls must be cleaned up so that they no longer rely on HP physically handling products. Good manufacturing practices require that HP track a number of pieces of information about the medical devices it manufactures. The information identification, recording, tracking, storing, and verification is currently attached to the product physically. Often customer order tracking documentation travels with the product itself. HP has grown accustomed to having the product in house, and some processes rely on being able to see

or get to the product during its manufacture. These processes must be changed so that the physical product and the information about it are separated. When a contractor is integrating software and hardware, it will still be HP's responsibility to maintain product and customer order information, and processes must accommodate that.

At a higher level, HP Medical must overcome a long-standing reluctance to share control and responsibilities with partners. HP knows that on its own it can manage medical device manufacturing, and all of the associated process controls. Because cost and capacity constraints have rarely plagued PMD, it has rarely felt the need to risk sharing responsibility with less directly controlled partner. This is a fear that PMD must overcome. PMD must also develop a greater general understanding of the regulatory implications and requirements in outsourcing, so that they can be properly handled.

HP must develop and gain internal buy-in to a new vision of its core activities. The top-down message must be that certain processes (such as hardware handling) are simply not in PMD's core competencies, and that HP would be better off moving them outside. Without this being fully understood, inertia and conservatism will set in. For example, consider the division of products for the implementation. The selecting of which products are in group A versus group B will probably entail some difficulty. Most people charged with managing product manufacturing will tend to imagine that their products should be in group B, due to the complexity they see in everyday management. If there is no strong feeling within PMD that outsourcing is the desired direction for its products, then there will be no impetus to volunteer one's product to be a trailblazer in the outsourcing implementation.

Finally, throughout the outsourcing process PMD must keep close watch over the market and its competitors, to ensure that HP retains its lead. Customers may expect unbundled software solutions faster than PMD has expected. Or, if competitors begin making advances on HP's leadership position, perhaps by offering more modular software products in HP's market space, then HP must adjust accordingly. In that case, the more leisurely recommended approach will have to be scrapped for a more aggressive implementation and development effort. By the time that could happen, PMD will have made some progress and will have some outsourcing experience. It should be more able to make an aggressive leap, and the market pressure should help HP focus on a tighter schedule.

4 Partner Considerations

The right partners are essential for HP's outsourcing effort to succeed. The two primary things that the partner brings to the relationship are cost savings and relief to HP's leadership from having to manage the processes the partner takes on. How well those two things are delivered to HP will depend on how well it fits with HP, and the level of trust HP has in the partner.

In a survey of automotive industry executives from suppliers, original equipment manufacturers (OEMs), and trade associations, Cross and Gordon (1995) found that the most important characteristic in an outsourcing partnership is trust. In the automotive industry, all players recognize their interdependence. As outsourcing relationships grow tighter and more intricate, and OEMs contract with fewer suppliers, trust only becomes more important. Although medical device manufacturing has special concerns, it is clear that trust must be at least as important there as in the auto industry.

There are many different kinds of potential outsourcing partners, from labor-only shops to full design-through-shipment operations. It's important to find a provider that matches PMD's requirements. Hilvers and Mucha (1993) describe several attributes that will be important for PMD to consider it its fit with its providers:

- **Service mix** - PMD will likely want a partner to help with development and optimization of integration and software load procedures initially. It will definitely want inventory purchasing and management services and configuration to customer orders. This points toward a fairly full-service outsourcer. PMD will probably want a partner that is willing to share its cost structure and collaborate on improvements, for a share of the cost advantage.
- **Technology level** - PMD's products use some very advanced hardware, and the partner must be able to manage that. However, volumes are fairly low, so technology oriented at extremely high throughput is not necessary.
- **Quality system** - The partner must be certifiable as a medical device manufacturer, and must reliably follow established procedures for device manufacture and testing.
- **Preferred manufacturing volumes** - PMD's small volumes make its products inappropriate for some of the largest contractors. However, PMD requires adequate capacity to handle some level of irregularity in its production schedule.

The most important of these fits for PMD will be the quality system, because of PMD's tight requirements in medical device manufacture. Particularly as PMD is still working out the

software/hardware dependence issues, it is imperative that the provider have quality of products and processes as a top concern. HP must be able to rely on the provider to follow processes as designed, every time. A culture dedicated to quality should be a basic requirement for PMD to have any trust in the provider.

HP's relationship with its providers, based on the discussion regarding PMD's core competencies, should be expected to be long-term. Rather than leaning hard on outsourcing providers and re-bidding its contracts every six months, HP must approach the vendors with a problem-solving attitude and one which supports the provider's right to make a living. Only in that way can HP develop mutual trust with its providers and realize strategic gains from outsourcing.

At the same time, HP must not lose its capabilities for developing integration processes and controlling medical device manufacturing. Integration of hardware and software should become a commodity service, if HP develops robust software. However, development of integration processes and controls must be understood by PMD or HP will have become dependent on its suppliers for knowledge in a key capability. HP cannot trust its suppliers to the point that it becomes complacent itself.

5 Potential Implementation Program

This program is not a recommendation, but merely an example of a transition plan that can get HP through the implementation within five years. Note that this work must be considered within the context of PMD's other products and their respective strategies.

Segment	Time Estimate
Transition Group A / Remove Technical Barriers	***3-4 years***
Re-orient R&D effort • Establish and monitor metrics to evaluate robustness of software; rank these metrics at least as highly as those measuring timely delivery of new functionality in products. • Initiate platform rationalization to reduce platforms and operating systems used. • Require desk hardware specifications be written for all new software products (whether or not additional hardware controls are required.)	6 months
Establish a United States merging capability • Set up HP warehousing and shipping facility distinct from the factory. • Ship all completed PMD product to the facility. • Procure Group A peripherals and network components directly into that facility, so that PMD no longer physically handles them. • Merge and ship consolidated customer orders from the facility. • Establish independent order management processes through the facility. • Turn over management of shipments from the facility over to sourcing partner. (Retain ownership of inventory)	1 year
Begin the process of eliminating the need for special hardware controls for integral products (Group B) • Test products with a variety of hardware that meet the desk specifications, rather than only with the specified hardware. • Simplify test and installation processes for products that are currently integral. • Decrease lot sizes (and increase order frequency) of hardware, so that variety of incoming hardware increases and problems are uncovered before products are outsourced. • Restructure products to isolate technically troublesome components.	3 years (concurrent with Group A activities)
Outsource procurement for peripherals and network components of modular products (Group A) • Establish demand management processes for these components within the merging facility. • Transfer operation of the processes to the partner within the facility. • Transfer ownership of managed inventory to the partner.	6 months

Outsource integration of hardware and software for Group A products • Establish software delivery and version control processes. • Establish integration capability and processes within logistics/merging facility, managed by HP. • Transfer management of integration processes to partner.	1 year
Complete elimination of hardware controls and modularization for Group B products • Transfer all test processes to integration stage. • Eliminate lot controls over hardware. • Expand desk specifications to allow greater freedom for hardware sourcing (various brands and models).	6 months
Begin developing fully unbundled (software only) products within Group A. • Develop hardware test processes that can be performed by software during installation. • Change software installation so that configuration to customer specifications can be managed either prior to software shipment or by codes provided to the customer based on the order. • Simplify installation processes for customer use.	1 year
Transition Group B	***~ 1 year***
Establish manufacturing capability for Group B products at partner • Refine software delivery and version control processes. • Build supplier competence in sourcing hardware based on desk specifications. • Initiate concurrent processes for Group B products at HP and partner.	6 months
Over time, re-allocate HP internal manufacturing capacity to other products (sensors, bedside monitors, etc.) effectively transitioning Group B products to partner.	6 months
Begin developing fully unbundled (software only) products within Group B. • Develop hardware test processes that can be performed by software during installation. • Change software installation so that configuration to customer specifications can be managed either prior to software shipment or by codes provided to the customer based on the order. • Simplify installation processes for customer use.	6 months (assuming Group A products already done)

The tasks are generally cross-functional in nature. As many of these tasks as possible should be done concurrently, to maximize speed while minimizing risks.

6 Conclusion

Hewlett-Packard is a company known for its emergent formulation of strategy, in that it takes stock of market conditions and its internal capabilities and steers the company toward new products and capabilities that ensure future profitability. Such strategy formulation has been a goal of this thesis.

The Patient Monitoring Division is positioned at the top of its market. It realizes that the market for its patient data management products will change, and PMD must change with it. Eventually, customers will demand, and competitors will offer, software solutions that are not dependent on a particular hardware platform, or even on who does the installation. PMD must have products and processes to support customer requirements.

The recommendations in this paper form a manageable path for PMD to follow in preparation for the market environment of the future. The leap from today's situation to unbundled software is too great to make without stepping stones. Outsourcing hardware handling is a set of steps that address most of the current difficulties with offering unbundled software solutions. Furthermore, whatever approach it takes, by the time HP offers unbundled patient data management solutions, it will have eliminated any special value in HP's handling of hardware, so outsourcing will have been an efficient path.

These recommendations cannot be simply taken and implemented directly. They must be worked into an overall strategy for all of PMD's products, not just patient data management solutions. More importantly, they must be organic, constantly updated to account for changing market and internal realities. However, it is hoped that they will provide a starting point for PMD's emergent product strategy for the next century.

Appendix 1: PC Supply Chain Cost Model

Note: This model provided much of the insight that became my arguments. There were two specific versions of the model and a generic version designed to be adapted to any of HP's PC-based products. Due to the proprietary nature of the detailed data, the detail of the model is not included here.

Problem Statement

PMD has multiple alternatives available to it for sourcing and integrating PCs for its products. PMD will not select a single supply chain for all of its products, but it needs a way to evaluate candidate supply chains and select a primary process for handling most of its products. PMD will not make these decisions based on cost alone, but it needs to be able to analyze the structural cost differences between supply chains as part of a larger analysis initiative.

For one particular product line, PMD is considering five different supply chain structures, illustrated below in figure A1.1.

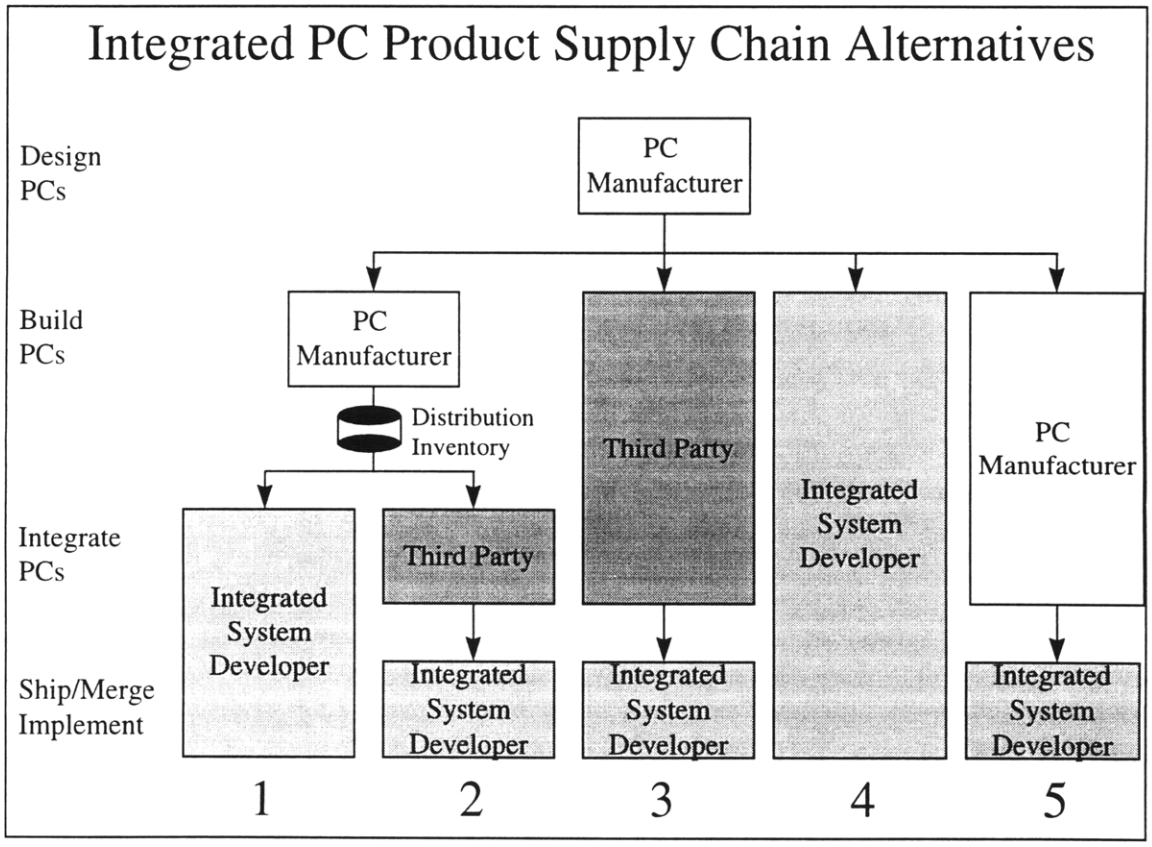

Figure A1.1: Integrated PC Product Supply Chain Alternatives

PMD must evaluate the cost differences within these supply chains during the design phase of the product, so that it can select a supply chain to be implemented and fine-tuned during the production ramp of the product. The goals of the model are to:

- Develop a model of the cost structures in a PC supply chain
- Investigate the comparative costs associated with each of the worldwide supply chain alternatives
- Facilitate selection of a supply chain through cost information as well as service and other considerations
- Develop and document a generic model for evaluation and selection of configured component supply chains.

Analysis Methodology

The model is based on a generic unit of the supply chain, called a "process step". Each step must receive inputs and perform the process. Outputs from the process are simply the inputs to the next process. Costs in the supply chain can be divided into:

- Process costs,
- Process management (or support) costs, and
- Boundary costs, those costs incurred because processes are performed by multiple partners.

This division of supply chain costs is illustrated in Figure A1.2.

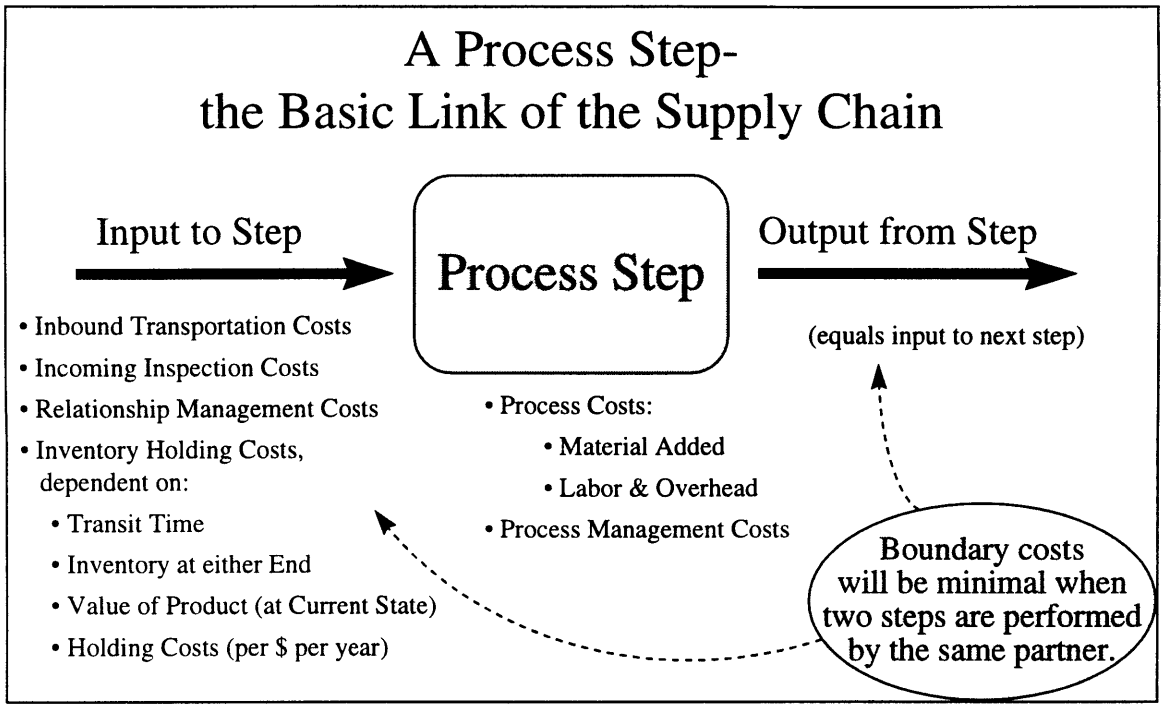

Figure A1.2: A Process Step

Each process step can be performed by any partner. However, the boundary costs for the inputs to a process step will probably be substantially higher when the step is performed by a different entity. Transportation costs will be higher if the partner is distant. Incoming inspection costs will likely only occur during a transfer between partners. (Note that process control inspection is considered to be a process cost.) Inventory holding will likely be greater, to account for communication and transportation delay and uncertainty. And certainly relationship management costs are substantially higher with additional partners.

The model, implemented in spreadsheet form using Lotus 1-2-3, aggregates all of the costs in the supply chain across all process steps from building PCs through shipment to the customer, and divides them by the cost categories described above. It would not be helpful for a comparison model to compare every process step individually, because the supply chains make trade-offs designed to minimize total rather than individual costs. Also, the comparison was made for early-stage planning, so detailed process step cost information was not available for all individual steps.

Estimates of real supply chain costs were made from within HP rather than basing the model on quotes from potential partners. This was to avoid bias from partner quotes that would be unprofitably low in an effort for the partner to gain HP's business, which might be substantial. The assumption was made that partners would have to recoup their initial losses eventually, and

that over time gains or losses in total supply chain efficiency will have to be shared amongst all partners.

Two further assumptions were made. First, it was assumed that homogeneous lot verification would not be required. This was reasonable because the costs of lot verification dwarf many of the other costs involved, apply to all five supply chains, and are expected to be eliminated by HP's development teams eventually. Also, costs were estimated subject to the constraint that PMD's on-time delivery rates must be maintained, and that product quality must be at least as good as it is currently. Where tradeoffs between service or quality and cost were inevitable, they were made at the expense of cost.

Costs were estimated based on a number of sources, including existing costing documentation for earlier versions of the product, activity-based costing analysis performed by HP's manufacturing organization, and interviews with HP engineers and managers. In cases where existing data was used, it was re-classified in terms of the new model, and updated or extrapolated where appropriate.

Results

Although detailed costs are proprietary to HP, the cost results are summarized in figure A1.3. Note that for supply chains 1 and 2, the building of PCs is considered part of material cost, while for supply chains 3-5, it is part of process cost. Supply chain 1 is HP's current supply chain for earlier products of the same type as that under consideration. Supply chains 2 and 4 are more expensive, by approximately 4% and 5%, respectively. Supply chains 3 and 5 are less expensive, by approximately 5% and 7%, respectively.

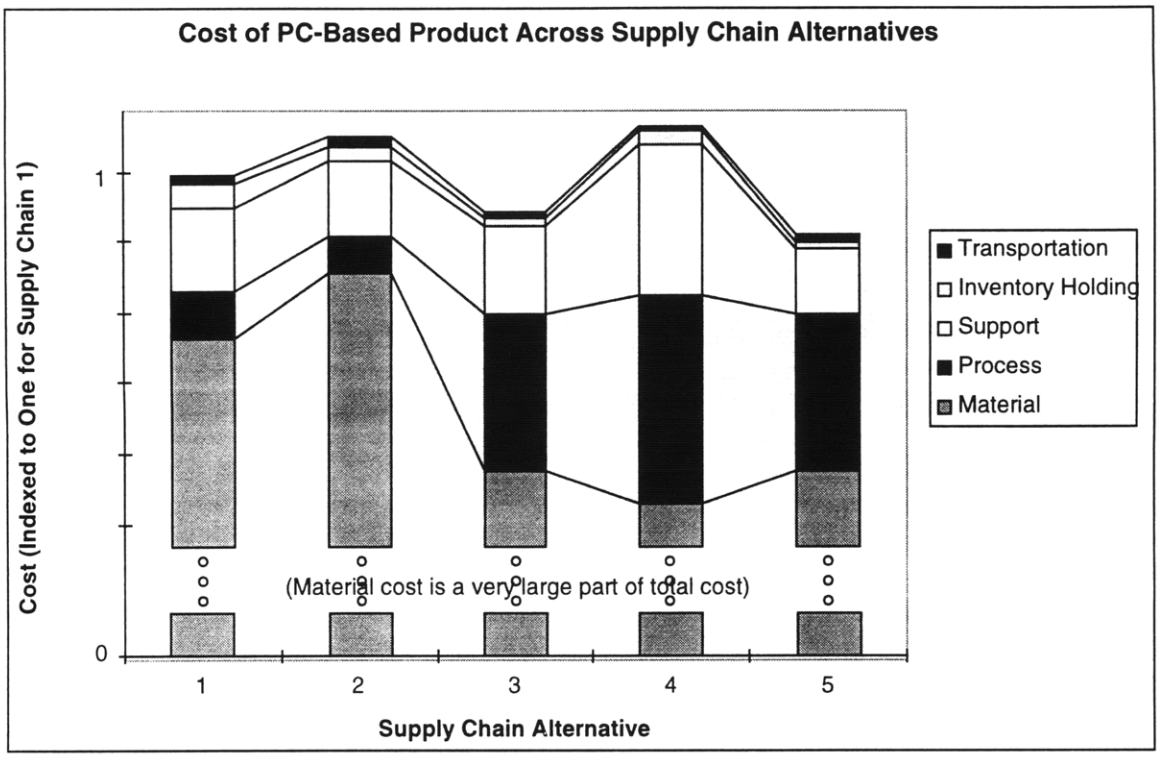

Figure A1.3: Cost of PC-Based Product across Supply Chain Alternatives

Material cost is a very large part of total cost. This makes total costs very sensitive to small percentage variations in material costs. The third party in supply chain 2 must mark up material that it handles, in order to make up its share of boundary costs and its own internal support costs. Thus supply chain 2 is the most expensive; it appears to be so from material costs, but in reality it is the increased boundary costs, as well as the necessity for several partners to show profit from their parts of the supply chain.

Scale also had a large effect on costs. Supply chain 4 is the most expensive, primarily because it would involve assembly of hardware without efficient scale. The volume of PCs that would pass through this process is too small to efficiently support the management of PC engineering and process control. The other supply chains spread large fixed process and process management costs over much larger volumes of PCs.

Conclusions

Several key learnings came from the cost modeling, including:

- Because transportation and inventory holding costs are so small compared to material costs for these products, it is imperative to focus on controlling material costs while investigating supply chain changes, rather than primarily on inventory or transportation reductions.

- Eliminating stages in the supply chain reduces boundary costs, which are generally not value-added. This is true as long as every process is performed by a partner that has a minimum efficient scale. PC assembly is the process with the largest minimum efficient scale.
- If PMD can eliminate the need for products to pass through its facilities at all, it may be able to improve the responsiveness and cost of the supply chain.

The above notwithstanding, the differences in estimated costs are certainly within the margin of error of the estimation techniques. This means that PMD should consider performing more detailed analysis. Furthermore, gross margins on these products are such that these differences in cost are not particularly substantial when considered against the products' selling prices. Thus PMD should consider supply chain changes more from a strategic than a cost perspective. Changes to PMD's product supply chains that actually increase costs could be small investments for significant performance and strategic gains in PMD's marketplace.

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