Outsourced Knowledge: Knowledge Transfer and Strategic Implications from Design Outsourcing

by

Peter L. Grant

B.S. Aeronautical Engineering
Rensselaer Polytechnic Institute, 1981

M.B.A.
University of Connecticut, 1997

Submitted to the Alfred P. Sloan School of Management
In Partial Fulfillment of the Requirements for the Degree of

Master of Science in the Management of Technology

at the

Massachusetts Institute of Technology
June 2000

Signature of Author: _____

MIT Alfred P. Sloan School of Management
May 8, 2000

Certified by: _____

James M. Utterback
Leaders for Manufacturing
Professor of Management and Engineering

Accepted by: _____

David Weber
Director, Management of Technology Program

Outsourced Knowledge: Knowledge Transfer and Strategic Implications from Design Outsourcing

by

Peter L. Grant

Submitted to the Alfred P. Sloan School of Management on
May 16, 2000 in partial fulfillment of the requirements for the
Degree of Master of Science in the Management of Technology

Abstract

Design is an especially effective means to transfer organizational product knowledge; yet, design outsourcing, or the contracting of a supplier to perform the design of a product or product component, has grown in acceptance and practice. Empirical evidence suggests that there are strategic risks for the contracting company, such as forward integration by the design supplier. There are also visible benefits, such as improving product innovation and overcoming resource limitations. To investigate the strategic implications of design outsourcing in conjunction with the knowledge transfer that takes place between the contractor and the supplier, six product development firms located in New England were interviewed. Their design practices and experiences in working with clients on many different design projects provided corroboration of and new insights into the risks and benefits from design outsourcing.

Additional research into design practices, design technology, the unique qualities of design knowledge, and the contributors to the transfer of knowledge during design support the argument that knowledge is transferred during design. The author proposes that a product is an embodiment of the tacit and explicit knowledge that is traded-off and integrated during design in a process that naturally employs collaboration. A relative qualitative measure of the amount of knowledge embodied by the product is called its knowledge intensity. Along with an alternative to the concept of a core product called the knowledge kernel, these concepts facilitate the important linking of knowledge and products during strategic outsourcing decisions.

To investigate the strategic implications of design outsourcing in conjunction with the knowledge transfer that takes place between the contracting company and the supplier, a systems dynamics model was developed. The model shows that the interactions of the many different causal-loops in design outsourcing results in an eight-to-three ratio of reinforcing feedback loops to balancing feedback loops. This result suggests that design outsourcing is a self-promoting practice that is difficult to balance and can lead to significant product knowledge transferred to the supplier.

Knowledge-based recommendations are offered for companies faced with design outsourcing decisions that include offensive and defensive tactics.

Thesis Supervisor: James M. Utterback
Title: Leaders for Manufacturing Professor of Engineering and Management

Table of Contents

Acknowledgements

I would not be at MIT for the past year of intense learning and exploration if it were not for the generosity of Eugene Buckley, president and chief executive officer, now retired, who selected me for this program and my sponsoring company. Thank you for a fulfilling, rewarding, and life-changing experience.

There are many other coworkers who supported my sponsorship and provided guidance while I was here but I would especially like to thank Don Gover, Beth Amato, Diane Mallory, Sam Garbo, Phil Potts, Richard Enders, Tom Harman, and Lee Teft. Thank you for making this possible.

As my thesis advisor, Professor James Utterback deserves recognition for his gentle guidance and help in ensuring my thoughts about the ramifications of design outsourcing were contained in this paper.

I have to thank the inspiring examples set by my mother and father. My mother's desire for continuous learning and her boundless energy frequently make me rethink what it means to age. I relish in the thought that my father, were he still alive, would be proud to see me graduate from MIT. His work ethic and character continue to influence me today.

There are many others whose help and inspiration have helped me get to this point in my life. However, there are three people who deserve the lion's share of the credit: my wife Janelle and my two sons, Alexander and Daniel. They have all witnessed this past year of excitement, learning, tension, anxiety, and lots of studying, which ultimately meant time away from them. They have supported me each day by making this experience easier because they were nearby. I hope in the years ahead they will look back on this time and realize that they too have learned from this adventure and that it was worth it.

Thank you Janelle. Thank you Alexander. Thank you Daniel.

Chapter 1. Introduction

1.1 A New Aircraft and New Partnerships Focus on Design

In the early 1990s, after years of preliminary and basic design activity, a large helicopter manufacturer announced it would pursue the development of a new medium-lift helicopter.[1] The new aircraft would satisfy a transport capability that was unfulfilled by products on the market or in development by other manufacturers.

The announcement of any new aircraft program is an exciting event because it brings with it the promise of years of employment and excitement designing, testing, manufacturing, and selling. In addition, as this helicopter company had seen with many of its other venerable helicopters, the first configuration tends to grow with time to many more configurations meaning continued employment designing, testing, manufacturing, and selling.

However, enthusiasm was dampened in some areas of the design and manufacturing organizations when it was learned that the project would be developed with five other partners located in Brazil, Spain, Taiwan, China, and Japan. Like many other aircraft companies, the high risk and cost involved in bringing a new aircraft to market made venturing out alone indefensible. Having five other strategic partners providing market access to these regions of the globe would help ensure sales before the first aluminum chip had been cut on a part. Besides, this was neither the first time for this aircraft company to enter into such an alliance, nor was it uncommon for the aircraft industry. Many successful precedents had already been established with U.S. companies entering into offset agreements with other countries to build sections of aircraft as part of the sales contract.

What especially caught my attention at the time as an airframe subsystem design engineer at a helicopter company was the announcement that the arrangement with the five international partners was a design and build contract. The five partners would be responsible for the airframe detail design and the fabrication of their modules of the aircraft. Although the company had outsourced portions of airframe design before, it had never done so to this extent. Perhaps those who said that anyone could do airframe design were right. Should an aircraft company ever

---

[1] The identity of the helicopter company is not revealed to protect it from any inadvertent disclosure of sensitive material.

contemplate the airframe subsystem as a core competence? Helicopter companies pride themselves on their dynamic system components such as the main rotor, transmission, flight controls, and propulsion integration. These were considered to be the core competency areas for the company and therefore, their detail design would be kept internal along with the primary integration and final assembly of the aircraft.

But, what about the fact that the airframe subsystem group does the integration of the other aircraft subsystems? Any other functional area, including the dynamic systems, needs to be integrated with the airframe group for structural support, dynamic response, electrical wiring supports and holes, hydraulic system supports and holes, crash retention, human factors considerations and the many other criteria that go into the final design of an aircraft. Even if the international partners were doing the detail design of just the airframe, they would have to learn something about the integration of these other systems to facilitate the completion of their design sections. Isn't this integration skill central to a helicopter company's ability to compete?

I realized that like other aircraft companies, this helicopter company really did not have a choice. It needed these partners to provide the resources, the risk sharing, and the market access that would be difficult and costly to gain otherwise. But, I was still troubled by the overall risk and benefit trade that is generally involved in the outsourcing of design.

1.2 Nagging Questions

It is now April of 2000. Each of the partners successfully delivered their portions of the helicopter prototypes that are currently undergoing flight. Assembly of the product went extremely smoothly – a testament to the integration efforts at the parent company and at the five international partners. The coordination that was enabled through the use of an electronic mock-up, advanced computer-aided design systems, a global network and dedicated personnel have realized a superior product.

But the general question still nags me. Does the outsourcing of design make strategic sense? After all, doesn't a product embody the creative integration of an organization's knowledge during design? I had learned that companies that create, disseminate and embody new knowledge in their products are successful and innovative. They are "knowledge-creating

companies" in the words of Nonaka.[2] When design is outsourced, doesn't this creative process break down while providing an especially effective means to transfer knowledge to the supplier? What are the long-term strategic implications of outsourcing design? Can a company retain its knowledge and a competitive advantage in the creation of new products if design is outsourced?

I also reasoned that if knowledge is flowing from the design buyer to the design supplier, there should be at least the potential for knowledge to flow from the supplier to the buyer. In other words, perhaps the strategic risks can be offset by potential strategic benefits that are independent of the obvious market access, supplemental resources, risk sharing and hoped-for cost savings that are typical outsourcing motivations.

Providing some help in answering these questions is my intention for this thesis. It involves examining the interplay of system dynamics that integrate the evolution of design methods and technology, knowledge management (including transfer and retention), specific industry considerations and strategic implications, both short and long-term.

1.3 Initial Evidence That Strategic Risks Exist

First I needed to know if my anxiety had any basis in reality. I looked to see if there were any instances where design outsourcing, not just manufacturing outsourcing, had apparently contributed to the transformation of a design supplier to an industry competitor. This would represent one example of the possible strategic risks associated with design outsourcing. If there were no evidence of such a transformation ever occurring, perhaps my concerns were overly pessimistic.

The following three examples convinced me that there could be strategic risks in transferring knowledge to design suppliers. They also convinced me that the decision to outsource design could easily be based on rational competition-based strategic thinking today, but could have long-term ramifications.

1.3.1 Schweizer Aircraft: From Aircraft Parts to Aircraft

Founded in 1939 as a manufacturer of gliders, Schweizer Aircraft expanded its manufacturing base to become a component designer and manufacturing supplier for the aerospace industry. In 1983, Schweizer began manufacturing the Model 300C helicopter, an

---

[2] Ikujiro Nonaka, "The Knowledge-Creating Company," Harvard Business Review, 69 (Nov-Dec 1991), pp. 96-104.

updated model of the Hughes Model 269A and 269B Series. (See Figure 1-1: Schweizer Aircraft Model 300C Helicopter.) The first Schweizer-designed helicopter was the Model 330 turbine, a light turbine training helicopter that expanded its product offerings from the single-engine piston helicopter line.[3] Today, Schweizer competes effectively in the light helicopter market against other, older manufacturers. Hughes Helicopter has disappeared through acquisitions by McDonnell Douglas, which was then acquired by Boeing. On February 11, 2000 the U.S. Navy announced, Schweizer's Model 330 with Northrop Grumman electronics won a contract for an unmanned aerial vehicle (UAV), beating offerings from both Sikorsky Aircraft and Bell Textron, two leading U.S. helicopter manufacturers.[4]

Figure 1-1: Schweizer Aircraft Model 300C Helicopter[5]

1.3.2 Callaway Cars C12: A New Car from a Performance Part and Service Provider

Reeves Callaway has a worldwide reputation for taking standard-production automobile engines and reengineering them to yield high-performance mechanical beauties. His company, Callaway Cars, has been doing this since he designed a turbo charger for the BMW 320 series on his own in 1977. In mid-1983, Alfa Romeo had Callaway design and install twin turbo chargers onto its GTV-6 for U.S. sales. In the 1990s, Callaway was hired by Ford to help its Aston Martin division with a Callaway developed engine for the Lagonda Virage. Callaway's relationship with

[3] Schweizer Aircraft web site, http://www.sacusa.com.
[4] Defense Systems Daily web site, http://defence-data.com.
[5] Schweizer Aircraft web site, http://www.sacusa.com.

General Motors has been especially bountiful for both sides with the success of the Callaway Corvette.[6]

In 1997, engineers at Callaway were challenged to design a car to race at Le Mans in the GT2 class, which meant it had to be derived from a street-legal production car.[7] Debuting in March 1998, the new Callaway C12 is a $185,600+ supercar that begins as a powertrain and chassis of a Corvette. (See Figure 1-2: Callaway Cars C12.) However, when completed (helped by its partner, IVM Engineering of Old Germany, in Munich) the all new carbon-Kevlar body, mechanicals and blueprinted engine provide no resemblance to its meager beginnings.[8] It now confidently challenges the supercar offerings from Ferrari, Lotus, Bugatti (Volkswagen), Jaguar and McLaren.

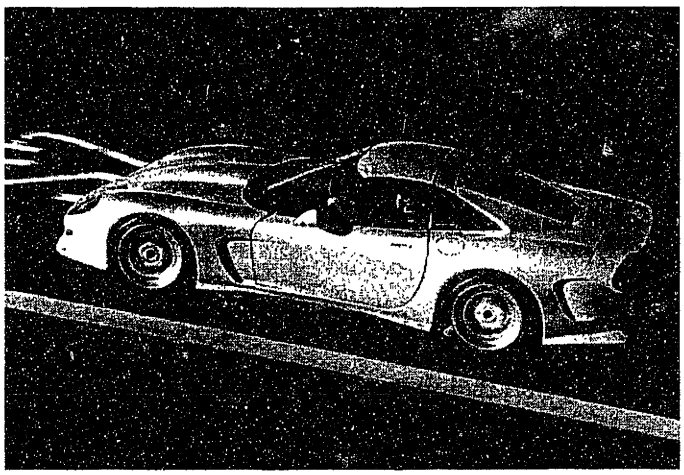

Figure 1-2: Callaway Cars C12[9]

1.3.3 IBM PC: Outsourcing and Open Architecture Changes the World[10]

IBM's development of the PC was originally touted as a new way of doing business. In 1981, when the PC was launched, IBM had outsourced the design of all of its major components. The microprocessor was from Intel, the operating system was from Microsoft (a tiny unknown at the time) and non-IBM manufacturers supplied other components. In essence, IBM leveraged its

---

[6] Callaway Cars web site, http://www.callawaycars.com.
[7] "Fast Car, Fast Development," Automotive Manufacturing & Production (May 1, 1999), p. 48.
[8] Paul Dean, "Behind the Wheel: Callaway's C12 is a Super Car Built for the Highway, if Not the Raceway," Los Angles Times (August 26, 1999), p. W-1.
[9] Callaway Cars web site, http://www.callawaycars.com.
[10] Henry W. Chesbrough and David J. Teece, "When is Virtual Virtuous? Organizing for Innovation." Harvard Business Review (January-February 1996), pp. 68-70.

technology integration expertise and strategic outsourcing to launch a new computer product in only 15 months. The open architecture of the design combined with the well-respected IBM name quickly expanded the whole market while grabbing market share away from Apple, becoming the number one supplier of microcomputers in three years.

The benefit to IBM, besides rapid development with fewer resources, was an obvious technological improvement from having many different resources. Knowledge of the architecture flowed between many different sources involved with the PC. Unfortunately, these suppliers eventually collaborated on their own, launching competing products. By 1995, IBM's share of the PC market had been reduced to 7.3% from what had been 45% ten years earlier. [11]

As Chesbrough and Teece note in their article, "When is Virtual Virtuous? Organizing for Innovation," "Key development activities that depend on one another must be conducted in-house to capture the rewards from long-term R&D investments. Without direct coordination, the necessary complementary innovations required to leverage a new technology may not be forthcoming."[12]

1.4 Thesis Focus

With some evidence of design suppliers using their knowledge to compete against their original contractor and a perception that there was a growing tendency to outsource design, I decided to delve deeper into the interrelationship of design, knowledge management and strategy. Combining interviews with product development firms and original equipment manufacturers, my objective for this thesis is to complete the following:

- Show that the practice of design outsourcing is becoming more prevalent.
- Identify reasons for an increase in the willingness and ability to outsource design, including innovations in design practice and technology.
- Show that design is a fertile ground for product knowledge growth.
- Show that product design outsourcing is especially effective for inter-organizational knowledge transfer.

---

[11] Henry W. Chesbrough and David J. Teece, "When is Virtual Virtuous? Organizing for Innovation." Harvard Business Review (January-February 1996), p. 68-70.

[12] Ibid.

- Show that design practice and technology innovations have contributed to the transfer of knowledge during design.
- Show that current outsourcing frameworks do not adequately address strategic considerations related to design outsourcing and the application of transferred knowledge.
- Identify the system dynamics interrelationships that link product architecture, outsourcing, design, the supplier, the contractor, and knowledge transfer.
- Identify the risks and benefits specific to design outsourcing.
- Provide recommendations for new considerations in design outsourcing decisions.

To clarify this thesis focus further, design outsourcing implies a much greater involvement of the supplier in the design than participation. The corporation must actually buy the design services of the supplier. Therefore, the supplier is responsible for the completion of the design, not simply provide design input to a design being done internally by the corporation.

Depending on the product architecture, design outsourcing might be done for a product assembly, product subassembly or product component. The term product will be used to generically refer to any of these instances except where it is important to differentiate the knowledge embodied by each case.

Finally, I will not attempt to make any clear distinction between design and engineering. My referral to design is intended to imply a process that includes technical and aesthetic aspects of product creation. However, design in this paper will always refer to much more than just styling or aesthetics. The knowledge content and strategic implications of design as described herein should make that clear.

1.5 Thesis Structure

Summarizing the essence of these goals into five distinct chapters creates an argument flow that can be summarized as follows: Innovations in design practices and technology have contributed to the willingness and ability of product firms to outsource design. Design is an especially effective means to transfer product knowledge and has been helped by innovations in practice and technology. Design outsourcing has strategic implications that are not fully considered by today's outsourcing frameworks. A system dynamics perspective helps to convey the organizational and environmental outcomes from design outsourcing. New considerations for design outsourcing decisions can be derived from this investigation.

To assist the reader in following the development of this thesis, the flow diagram in Figure 1-3: Thesis Structure will be repeated at the beginning of each chapter. Highlighted regions of the diagram will position the reader to what portions that chapter will address.

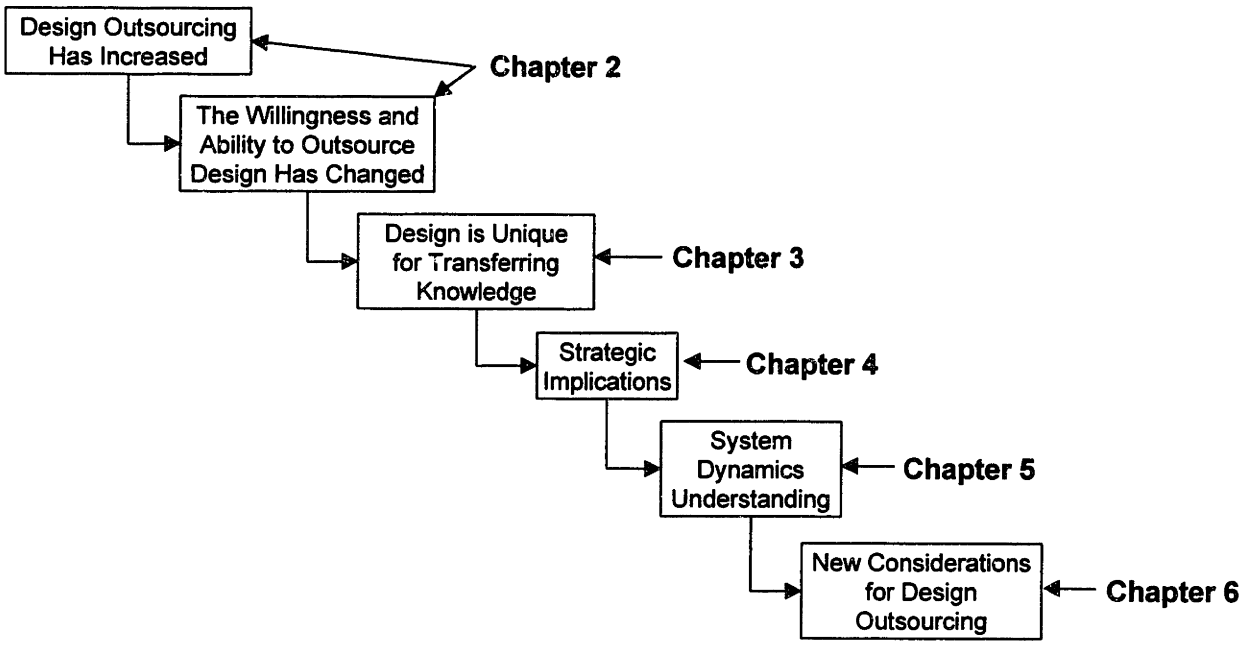

Figure 1-3: Thesis Structure

1.6 Research Method

Design outsourcing can be a contentious topic. The stakeholders include design professionals on the sides of the contractors and suppliers as well as the entire corporation, which is looking to benefit from design outsourcing in some fashion. When considering what research approach to use, I realized that I had my own biases to contend with, having been in aircraft design for over 18 years. I was concerned that too much of a focus on this unique industry would blind me to trends and considerations central to other industries, making it more difficult to objectively look at the benefits of design outsourcing practices.

I also realized that the speed of change in the aircraft industry is excruciatingly slow compared to other industries, such as the automobile or computer industries. Fine[13],

[13] Charles H. Fine, Clockspeed: Winning Industry Control in the Age of Temporary Advantage, (Reading, Mass: Perseus Books, 1998).

Christensen[14], and Baldwin and Clark[15] selected the computer industry in their research because, as Fine noted, it is like the fruit fly of biologic research – its life cycle is so fast, strategic actions and reactions play themselves out very quickly. Using Fine's nomenclature, the "clockspeed" of the computer firms is faster. Fine defines clockspeed as the rate of evolution for an industry depending on its product, process and organization clockspeeds.[16]

In the design community, product development firms are the fruit flies for much the same reason. They are involved in many different technologies and with many different contracting firms, progressing at a pace much faster than that of the helicopter industry. These firms have their pulse on the latest design practices and teamwork; although, because of their resources, they may not have the same design tool sophistication. Because they engage in many different projects in parallel and/or in rapid succession, their practices tend to reflect the portfolio of projects in their engagements. That is, their objective is to learn from their projects, thereby providing some key insights into how knowledge is transferred, captured and then reapplied.

For these reasons, interviews were conducted with six different product development firms in Massachusetts and Connecticut. These firms were not randomly selected, but were chosen from a much larger list of product design firms.[17] Each firm was then reviewed through its Internet available information to ascertain its heritage, its clients, its portfolio of products, and perhaps a stated design philosophy. In particular, I looked for companies that represented a cross section of products and styles, but especially those that appeared to have a product or products that required integrating different technologies. I was not interested in firms that were just industrial designers, but those that had also demonstrated an engineering design capability.

The six companies are: Product Genesis, Bleck Design Group, Herbst Lazar Bell, Product Insight, Altitude, and 9th Wave. The interviews were conducted in person or over the telephone from March 4 to March 10, 2000. Each of the selected companies is a product development firm. In addition to offering industrial design services, these firms have a suite of additional services

---

[14] Clayton M. Christensen, The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail (Boston, MA: Harvard Business School Press, 1997).

[15] Carliss Y. Baldwin and Kim B. Clark, Design Rules: The Power of Modularity (Cambridge, MA: MIT Press, 2000).

[16] Charles H. Fine, Clockspeed: Winning Industry Control in the Age of Temporary Advantage (Reading, Mass: Perseus Books, 1998), p. 6.

[17] Core77 web site, http://www.core77.com/ has a listing of design firms in New England.

for their clients. Although varying from firm to firm, the expanded services include mechanical and electrical engineering and analysis, software programming, product and marketing strategy, rapid prototyping, and manufacturing.

The interviews were conducted with a set of guided questions, but were allowed to let the interviewees, of which four out of six were the founders of their firm, freely expand on their philosophies towards design, design contracting, creativity and competition. My hope was to gain a truer sense of their relationship with their clients. I believe this strategy was successful.

Although this story began with an aircraft company, the ramifications of design outsourcing, knowledge transfer and strategic implications are generically applicable to any product-based company. Understanding these implications should be part of any strategic outsourcing decision, regardless of the industry. For this reason, the use of product development firms to study these interactions does not necessarily detract from the application of this work to other industries.

1.7 Chapter Summary

Design outsourcing raises significant questions about its viability as a long-term successful corporate strategy. Initial evidence appears to show that there are strategic risks associated with design outsourcing centering on the knowledge transferred during design. The following chapters will explore the interrelationship of design, knowledge transfer and strategy in the context of outsourcing. Interviews with six product development firms will be used to support the findings of the thesis.

Chapter 2. Changes in Design

As shown in Figure 2-1: Thesis Structure Highlighting Chapter 2 Focus, this chapter examines the practice of design outsourcing and provides evidence supporting that there is an increase in this practice. The reasons why it has increased are then reviewed by describing how design practices, technology, product architecture and competitiveness have increased the willingness and ability of firms to outsource design.

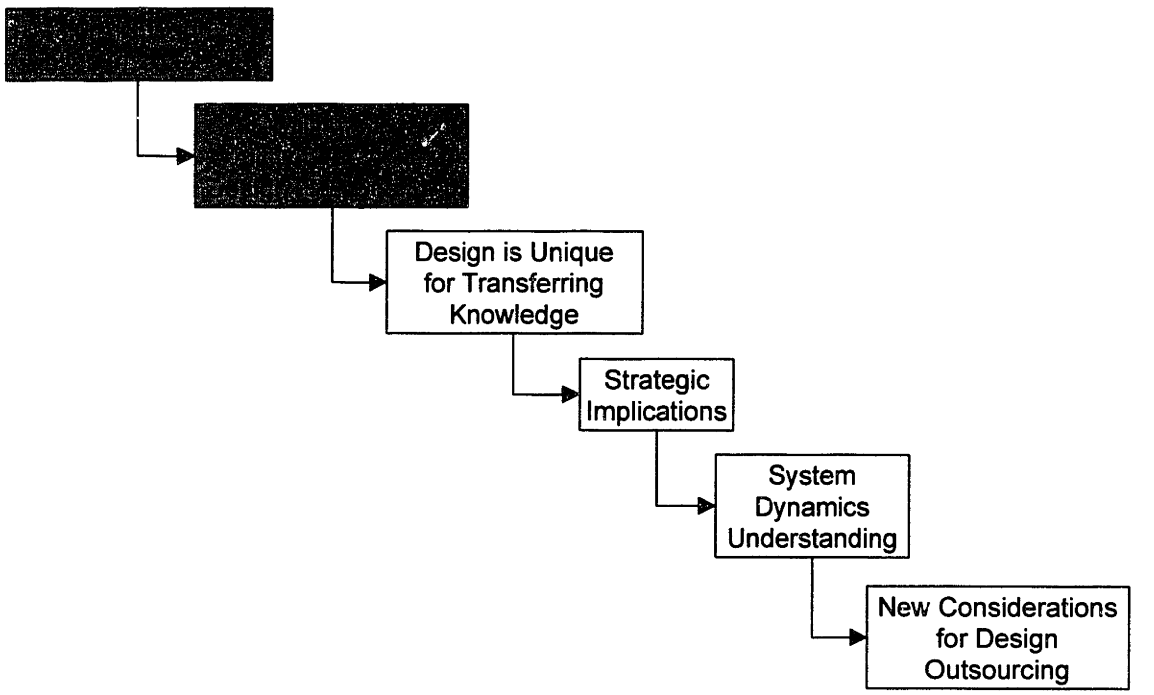

Figure 2-1: Thesis Structure Highlighting Chapter 2 Focus

2.1 Design Outsourcing Is Increasing

The decision to outsource a new helicopter's airframe subsystem design in its entirety was a surprise because of my own biases towards design. My 18 years as a design engineer for fixed-wing and rotary-wing (helicopters) aircraft have led me to believe that the success or failure of a product rests on its design. If a product is well designed it will not only meet or exceed the customers' expectations, it will be easy to manufacture and will have low life-cycle costs. The product will be valued, creating value for the firm through customers' future purchases. Therefore, the success of a product firm ultimately rests with its ability to design valued products. Sanderson's and Uzemeri's identification of outstanding long-lived product models called "business classics" highlights the potential economic gain from well-designed

products.[18] Similarly, Lehnerd's work at Black and Decker showed that even mature products could be dramatically revitalized through outstanding design, reaping substantial competitive advantage for the corporation.[19]

Design is a competence that should be considered core to the corporation because it can provide access to a wide variety of markets through the products that result, it adds significant perceived customer benefits to the product and it is a skill that competitors find difficult to imitate. These characteristics are also three identifiers of a core competence as identified by Prahalad and Hamel in their seminal work, "The Core Competence of the Corporation."[20]

Yet, I perceive a growing trend to unbundle design from the product value chain – to view design in the same light as contract manufacturing has been for over a century.[21] The increasing pressure on corporations for financial performance has coupled with reengineering and core competency strategies to encourage companies to outsource those activities that do not provide competitive advantage.[22] Each of the interviewed product development firms concurred that they were also seeing more design contracting. One firm offered the comment that "it's a huge pond" regarding growth in the product development industry.[23] Several other surveys, presented below, provide additional evidence that design outsourcing has grown.

2.1.1 American Management Association Survey (1996)

In a job elimination survey conducted by the American Management Association (AMA) in 1996, a growth in outsourcing was used by respondents to explain part of the growth in job elimination. To study this aspect, the AMA conducted an outsourcing survey among 619 companies of which 337 manufactured products. Thirty-seven activities of an organization were

---

[18] Susan Walsh Sanderson and Mustafa Uzumeri, Managing Product Families (Irwin/McGraw-Hill, 1997).

[19] Alvin P. Lehnerd, "Revitalizing the Manufacture and Design of Mature Global Products," Technology and Global Industry: Companies and Nations in the World Economy (National Academy Press, 1987), pp. 49-64.

[20] C. K. Prahalad and Gary Hamel, "The Core Competence of the Corporation," Harvard Business Review 68 (May-June 1990), pp. 79-90.

[21] Simon Domberger, The Contracting Organization: A Strategic Guide to Outsourcing (New York: Oxford University Press, 1998), p. 54. For example, gun making in England in the nineteenth century employed a master gun maker who acted as a contracting company, outsourcing the manufacture of gun parts and final assembly.

[22] Adrian J. Slywotzky, Value Migration: How to Think Several Moves Ahead of the Competition (Boston, MA: Harvard Business School Press, 1996), p. 236.

[23] Ed Gilchrest, Interview at 9th Wave (Southbury, MA: March 4, 2000).

queried to see what was the current level of outsourcing, including product and component design. These particular questions were asked of just the firms that manufactured products.

The results strike a familiar chord. In 1996, of the 337 manufacturing companies, 19.9% outsourced component design – a 42.6% increase from 1994 to 1996. These same companies predicted that by the year 2000 outsourced component design would be 22.8%. For product design, the survey results were similar. These companies were currently outsourcing 13.9% of their product design – a 74.1% increase from 1994 to 1996 – and expected the percentage of product designs outsourced to rise to 17.5% in 2000.[24]

2.1.2 American Society of Engineering Management Survey (1997)

In 1997, the American Society of Engineering Management conducted a survey of over 600 executives in U.S. manufacturing, institutional/utility and trade/services companies. The average percentages of outsourced, or contract engineering at the companies ranged from 48% to 65%. The same survey identified the leading driver for outsourcing as "engineering needs" in "over 60% of the cases to provide a 'special capability.'"[25]

2.1.3 Drexel University and Industrial Designers Society of America Survey (1998)

The Industrial Designers Society of America (IDSA) is a 3200 member organization of professional designers whose mission is to promote the benefits of design. The 1998 Drexel University/IDSA Employment and Education Survey of U.S. industrial design offices (179 responses of 787 solicitations) offered another supporting perspective on the growth of design outsourcing. From 1993 to 1997, these firms had seen a 47% growth in their hiring with a 25% jump just in 1997. They estimated a further 21% growth by the end of 1998 and another 50% by the end of 1999.[26]

---

[24] Maurice F. Greaver II, Strategic Outsourcing: A Structured Approach to Outsourcing Decisions and Initiatives (New York: AMACOM, 1999), pp. 299-308. This data was attributed to Eric Rolfe Greenburg and Carol Canzoneri, Outsourcing: The AMA Survey (AMA Research Reports, 1997).

[25] Arnold J. Rothstein, "Outsourcing: An Accelerating Global Trend in Engineering," ASEM Engineering Management Journal, 10 (March 1998), pp. 7-14.

[26] Kristina Goodrich, "First-Ever Survey Projects Dramatic Growth in U.S. Industrial Design Employment," Industrial Designers Society of America web site, http://www.idsa.org/.

2.1.4 Kimzey Study (1998)

There have been other attempts to quantify the degree to which external sources of knowledge are embedded in the products of manufacturers. Kimzey at Vanderbilt University examined the outsourcing of technology in new product development. One of his primary objectives was to define how the use of technology outsourcing improved new product development. As part of this effort, he conducted an in-depth survey of "discrete part manufacturing companies with a track record of rapidly developing technologically intensive products. The types of firms examined were technologically strong, primarily non-defense, manufacturing companies."[27] Thirty-two companies – large and small, with average revenues over $16 billion in 1996 and 45,000 employees – took part in the detailed study in both Japan and the U.S.[28] Of the firms studied, 40% of the manpower to bring the sample new products to market came from outside sources. The findings also show the difficulty that some organizations are having with this change in design sourcing. In one example, the company gleaned much of its pride from its internal design capabilities, yet over 50% of its latest product's design had been outsourced.[29]

According to Kimzey, increasing design outsourcing is not just a U.S. trend. Between 1986 and 1996, while the U.S. increased its reliance on external design by 55%, the Japanese increased its reliance on external design by almost 75%.[30]

2.2 Increasing Willingness and Ability to Outsource Design

Like the surveys done by the American Management Association, the American Society of Engineering Management, and the Drexel University and Industrial Designers Society of America, Kimzey's study corroborates my perception of this growing trend to outsource design. What I did not understand was why. This question can be broken into two parts. Companies must not only be willing to outsource design; they must also find or derive the ability to outsource design. The following paragraphs examine the contributions of willingness and ability and how

---

[27] Charles H. Kimzey, Jr., "Outsourcing Technology for New Product Development: A U.S.-Japan Study of Technology Strategy," Ph.D. Dissertation in Management of Technology, (Nashville, TN: Vanderbilt University, 1998), p. 2.
[28] Ibid., pp. 113-115.
[29] Ibid., p. 195.
[30] Ibid., p. 268.

they have augmented one another to increase design outsourcing. In Chapter 3, these contributions will be related to changes in knowledge transfer during design, a primary strategic consideration for design outsourcing.

2.2.1 A Willingness to Outsource Design – Why Outsource Design?

In retrospect, it probably should not have been a surprise that when I began peering into different recommended decision-making processes for determining when and what to outsource, I found that the dominant motivation suggested for outsourcing was tied to the bottom line. The justifications for outsourcing have historically been derived from its relationship with improving operational performance. Purchasing organizations were developed to coordinate and negotiate the many different externally purchased goods and services needed to keep factory production moving. In turn, these organizations have typically been rewarded on their ability to save cost. This may seem rudimentary, but the implications are deeper. With a financial perspective tied to outsourcing and a strategic perspective that is focused on short-term savings or resource limitations, an outsourcing strategy develops that ignores strategic effects, especially those with long delays (effects from a slow industry clockspeed). These findings originally bolstered my perspective that design outsourcing was not a beneficial practice for firm competitiveness. However, the product development firm interviews identified a number of reasons that contradict this admittedly simplistic view. They are presented below:

2.2.1.1 Knowledge Transfer

The clients with which the product development firms work know that their competitors are getting technology from many different sources, including contract design firms. Therefore, some firms have linked a competitive benefit to outsourcing design. The bilateral transfer of knowledge during design collaboration for competitive advantage is a phenomenon that is both obvious and subtle. Of course, both the client and the product design firm can learn from one another during the design of a product, but the subtlety is recognizing this fact so that it can be exploited through knowledge management practices.

In an interview with the manager of the airframe organization for a large aircraft company, he commented that one of the things they learned from outsourcing the design of aircraft subassemblies is that they were not the leaders in some design practices that they thought

they were. In other words, design outsourcing provided a means to benchmark the company against other companies in the same industry.[31]

Each of the product development firms was cognizant of the opportunities to learn created by their client engagements. They mentioned explicitly the collaboration process with their clients and how they learned about the technology sufficiently to be able to design a product around it. In essence, they know that during the design of the product, knowledge about how to innovate, the product development process and the latest in design trends can be passed to the client just as much as knowledge about the product can be passed to the design firm or the client. Product Genesis has seen some of their clients learn not only about their product development process, but has seen their client come out with incremental improvements on their products that are directly derived from things learned from Product Genesis. These same clients, though, typically return back to Product Genesis for the "next big thing."[32] Bleck Design suggested that one of the outcomes of their work is a "big cross-linked network of consultants and people that can work together."[33] The exchange of knowledge between the original equipment manufacturer (OEM) and the supplier is shown diagrammatically in Figure 5-2: Knowledge Stocks and Flows with Driving Variables.

2.2.1.2 Resource Limitations

Some clients use the product development firms because they do not have the internal resources necessary to bring their product idea to fruition. Reasons cited for this resource shortage varied and included clients wanting to smooth their direct manpower loading by avoiding layoffs or start-ups not having yet established a product development capability. These reasons cited by the product development firms corroborate a finding from the American Society of Engineering Management survey, 83% of the executives surveyed stated that an important reason for outsourcing was that resources were not available internally.[34]

Related to the firms that refrain from hiring additional designers to smooth their direct staffing numbers, companies are intent on remaining lean, seeing direct design staff as an

---

[31] Interview on March 6, 2000. The name of the company has purposely been withheld.
[32] Brian Vogel, Interview at Product Genesis (Cambridge, MA: March 6, 2000).
[33] Jim Bleck, Interview at Bleck Design Group (Chelmsford, MA: March 8, 2000).
[34] Arnold J. Rothstein, "Outsourcing: An Accelerating Global Trend in Engineering," ASEM Engineering Management Journal, 10 (March 1998), p. 11.

expensive proposition for the number of products that they produce. To avoid a hire-then-fire cycle of employment, firms are hiring at a low level and then outsourcing any overflow work. This trend is represented graphically in Figure 2-2: Smoothing Direct Labor Demand Peaks with Outsourcing below, where peak resource demands are smoothed by outsourcing.

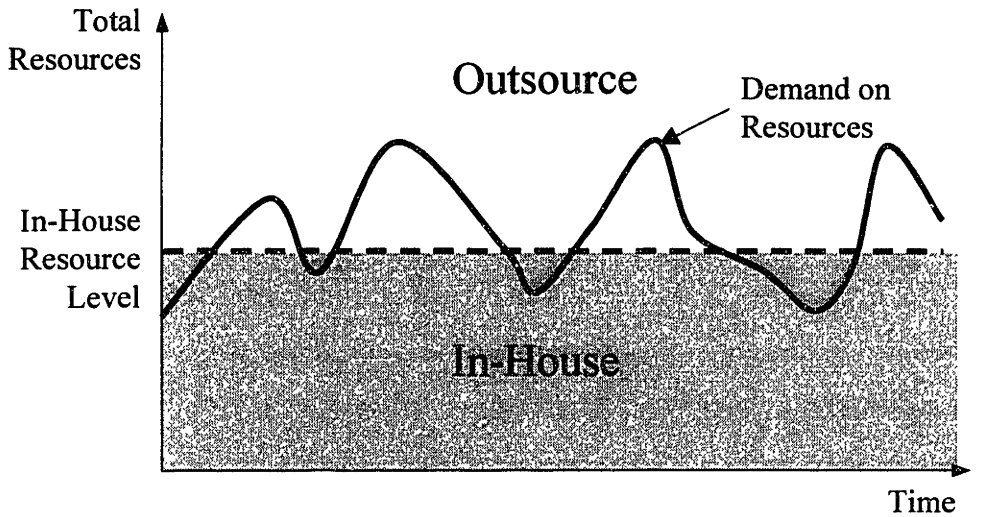

Figure 2-2: Smoothing Direct Labor Demand Peaks with Outsourcing

The product development firms also cited the current economic boom as a contributor to the resource difficulties of some companies. The tight labor market for specific skills, such as design, makes attracting and retaining retain skilled indigenous design staff more difficult. Their clients come to them because they are unable to hire and train the designers that they need to work on their own projects.

Another result cited was the kind of projects that they are asked to do for their clients. Their clients may have an internal design staff doing new product design while they outsource the improvements or next generation of an existing product. For example, 9th Wave said 50% of its current business is redesigning an existing client's or a client's competitor's product.[35]

2.2.1.3 Skill Limitations

One result of resource limitations is that firms may not have internally the skills that are needed to develop their products and are unwilling or unable to train or hire those skills. As the design consultancy industry shifts from industrial design to product development with a host of

[35] Ed Gilchrest, Interview at 9th Wave (Southbury, MA: March 4, 2000).

other service offerings, these firms are finding that their increased expertise in some areas has attracted clients. For example, 9th Wave said that they find themselves being contracted by manufacturers and industrial design firms to take advantage of 9th Wave's skills in mechanical and electrical engineering.[36] A side benefit of using outsourcing, according to Bleck Design, is that the company can contract with the "really good skills" and not just those that are resident.[37]

2.2.1.4 Innovation

Many of the interviewed product development firms saw their clients outsourcing to improve the innovation in their products. Several different fundamental causes were stated that had been derived from interactions with their clients.

One common cause for innovation driven outsourcing is the recognition that a permanent design staff in an organization cannot possibly see the diversity of projects that a designer in a product development firm would see. Each of the interviewees emphasized the knowledge building that took place from project-to-project (which will be discussed more in Chapter 3) as well as the creativity that builds from diversity. As one firm president stated, past products and the learning resulting from them are the keys to innovation. The firms innovate off the back of their previous engagements.[38]

According to the product development firms, clients also recognize that the product development firms may be seeing the latest in technologies and trends from their clientele.[39] In this way, the client can leverage the firm's diverse technology exposure with the hope that it will lead to a more innovative solution to its own development problem. An internal design staff has only experiences with its own products from which to build a new design. This can create what one firm called "incestuous thinking," where each new product looks like a relative to the previous product.[40] Companies employ outside firms to get away from this phenomenon and inject new life – fresh thinking – into its products.

Bleck Design said they have clients that have seen great designs emanate from their one or two designers, but that there is a benefit to having a team of designers working on a design.

---

[36] Ed Gilchrest, Interview at 9th Wave (Southbury, MA: March 4, 2000).
[37] Jim Bleck, Interview at Bleck Design Group (Chelmsford, MA: March 8, 2000).
[38] Ed Gilchrest, Interview.
[39] Ibid.
[40] Anthony Pannozzo, Interview at Herbst Lazar Bell (Waltham, MA: March 10, 2000).

The power of a team of experienced and creative consultants working on a product is not lost on these clients. Small companies cannot support such teams internally because they do not have the numbers of people or the diversity of products to maintain their creative skills.[41]

2.2.1.5 Time-to-Market

Achieving a faster time-to-market is the result of having the resources that can be committed to a project and the incentives and methodology that can provide a faster delivery. A benefit for their clients mentioned by one product development firm and reinforced by others was the leverage that clients have for price and schedule.[42] These companies have found that faster product launches may be achieved by executing the design outside of their in-house organizational constraints and leveraging this buyer power. The firm knows that there are other design suppliers that it is competing against for the contract and must provide the performance needed to retain its client and possible repeat business.

According to the product development firms, they are also able to perform product development faster because of better skills at product development honed through many different engagements. They have learned methodologies that contribute to a faster development time including specific skills in improving creativity, such as brain-storming.

Product Insight has been told by some of their clients with internal design staffs that they are outsourcing design more for the time-to-market benefits it provides. Having multiple sources for design permits more products to be done in parallel, shortening development time.[43]

2.2.1.6 Cost

As with time-to-market, the incentive to retain the client through superior performance can also lead to cost benefits normally not realizable internally. Although the usual contract arrangement is pay-by-the hour, there were other arrangements described that have been used to offset the cost of design. Sometimes the firm will trade its services for an equity share in the product success or trade a guaranteed manufacturing contract for the design. These alternative arrangements are especially attractive to start-ups who may be strapped for cash.

---

[41] Jim Bleck, Interview at Bleck Design Group (Chelmsford, MA: March 8, 2000).
[42] Brian J. Matt, Telephone interview with Altitude Inc. (Somerville, MA: March 10, 2000).
[43] Telephone interview with Product Insight (Acton, MA: March 8, 2000).

The desire to reap cost benefits by outsourcing can be pushed especially hard by firms making a commodity product with substantial price constraints. These firms shop the design of the product in hopes of getting the best "bargain," according to Herbst Lazar Bell. However, it is also felt that these kinds of firms ignore the longer-term implications of a poor design.[44]

2.2.1.7 Venture Capital Availability

Another firm correlates more design outsourcing with the abundance of venture capital prevalent since the late 1990s. As new money flows into technology start-ups, these firms are under pressure from the venture capital investors to quickly get into the market, seize market share, and achieve a return. Without any product development experience and few resources, these firms rely on the skills of the product development firms to accelerate the process, hastening their time-to-market.[45]

2.2.1.8 Firm Focus

In the interviews with the product development firms, they stated that a focal point for the design at the client was a requirement within the firm. In other words, after outsourcing the design, the client shifts from doing the design to managing and coordinating the design along with the rest of the product development. Some product development firms stated that this capability is best achieved when the focal point has design experience.

One product development firm noted that some of their clients are not interested in gaining product development skills. The client's core competency is in the science and that is where they would like to allocate their internal resources.[46] Developing and packaging the product for manufacturing is a skill that they neither have nor intend to develop. Sustaining this strategic tactic may be successful only as long as they are able to advance the technology.

2.2.1.9 Political Motivations

In larger organizations, the interplay of different groups may result in products that are "designed by committee." One product development firm interviewed said they have had clients who have recognized the freedom that an outside firm possesses in executing a design without

---

[44] Anthony Pannozzo, Interview at Herbst Lazar Bell (Waltham, MA: March 10, 2000).
[45] Jim Bleck, Interview at Bleck Design Group (Chelmsford, MA: March 8, 2000).
[46] Brian Vogel, Interview at Product Genesis (Cambridge, MA: March 6, 2000).

many of the in-house political constraints. This same freedom often translates to faster design completion because recommendations are coming from outside the firm, without any perceived political subjectivity.[47]

2.2.1.10 Organizational Size

A conclusion drawn from the product development firm interviews is that the size of an organization appears to strongly influence the decision to outsource. The smaller the organization, the less likely it has all the skills necessary to effectively develop and market a product. The product development firms interviewed reinforced this intuition through their experiences with small clients. Larger organizations tend to have in-house capability but are driven to outsource product development for other reasons.

Smaller organizations are also less likely to have the knowledge base derived from a diverse history of projects that can be the catalyst for innovation. When smaller companies outsource their design, they hope to gain the diverse expertise their supplier has gained in working many different projects.

2.2.1.11 Acceptance of the Benefits of Design

Along with a general growth in the outsourcing activities, several of the design firms believed that the increase in outsourced design was partially related to a change in how design is perceived. In their opinion, firms now view product development as a design problem, not just an engineering problem.[48] Part of this change might be credited to Business Week and their highly publicized sponsorship of the Industrial Designers Society of America (IDSA) Annual Design Awards, which awards gold, silver and bronze medals to design firms and manufacturers for products that have been selected for outstanding design. One design firm executive ironically noted that now "everything is designed."[49]

2.2.1.12 Reasons Related to Product Architecture

Although none of the product development firms mentioned this explicitly, other work has shown that the architecture of the product is related to the willingness of the company to

---

[47] Telephone interview with Product Insight (Acton, MA: March 8, 2000).
[48] Jim Bleck, Interview at Bleck Design Group (Chelmsford, MA: March 8, 2000).
[49] Ed Gilchrest, Interview at 9th Wave (Southbury, MA: March 4, 2000).

outsource. That is, the more modular the product architecture, the greater the willingness for a part of the product to be outsourced, leading to more outsourcing. A system dynamics model of this relationship is represented in Figure 2-3: System Dynamics Model of Product Modularity on Design Outsourcing, illustrating the reinforcing feedback loop that this system creates. I call it the Mass Customization Loop to emphasize the increased modularity promoted by Pine to achieve mass customization in his book Mass Customization.[50] Pine also recognizes that this modularity plays into an ability to disaggregate the value chain.

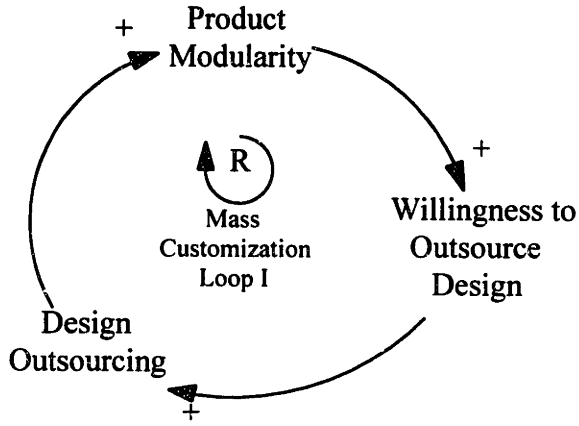

Figure 2-3: System Dynamics Model of Product Modularity on Design Outsourcing

This intuitive connection is supported by the work of Ulrich and Eppinger. They note that it is easier to split development responsibilities with a modular architecture. In this manner, the functional interactions with other parts, or chunks, of the product, are relatively limited and known.[51] For example, in aircraft development, it is common to create interface control drawings to simplify the management between these product chunks and ensure the design supplier satisfies known constraints.

2.2.1.13 Reasons Related to Design Process and Technology Changes

The product development firms were not able to directly link changes in the design process to an increased willingness to outsource. Although product development teams and close collaboration are prevalent today, it is very different from when it was typically performed on a

---

[50] B. Joseph Pine II, Mass Customization: The New Frontier in Business Competition (Boston, MA: Harvard Business School Press, 1993).

[51] Karl T. Ulrich and Steven D. Eppinger, Product Design and Development (McGraw-Hill, Inc., 1995), p. 137.

drafting board in two-dimensions using ink-on-Mylar drawing practices (Figure 2-4: Drafting Boards in Typical Engineering Work Area, 1985).

Figure 2-4: Drafting Boards in Typical Engineering Work Area, 1985[52]

In the 1980s, two-dimensional computer-aided drafting became prevalent and three-dimensional modeling began to advance in capability. In the 1990s, advances in three-dimensional computer aided design, engineering and manufacturing with solid modeling, advanced prototypes and virtual simulation capabilities of manufacturing and operational processes combined with web-enabled information transfer to simplify the coordination between different product chunks.[53] Perhaps the most established signifier of this capability is the electronic mock-up – a three-dimensional virtual assembly of the product compiled from the individual computer models that define its parts.

In addition to these technological leaps influencing the design process, the management of design has also changed. Product development has changed from "throw it over the wall" when a design moved serially from the design group and then to manufacturing, to a process using product development teams comprised of different functional stakeholders collaborating

---

[52] --- News (April 1985) p. 3. Original caption reads "Daylight from perimeter aisles complements overhead fluorescent lighting in a typical engineering work area. Modular offices can be seen in the rear." The name of the aircraft company has been purposely left anonymous.

[53] Adrian J. Slywotzky, Value Migration: How to Think Several Moves Ahead of the Competition (Boston, MA: Harvard Business School Press, 1996), p. 254-257.

early in the design process. In the same way technology has influenced other processes, video conferencing on the Internet and software that permits real time collaboration between physically separated designers using the same design computer model is making the virtual collocation of product development teams feasible.

These advances may contribute to a willingness to outsource, though Altitude believes that factor is not currently in the mindset of their clients when they decide to outsource. However, Altitude did say that the Internet has been "awesome" by eliminating the need for face-to-face meetings and enabling a review of images on the computer while talking on the phone.[54]

2.2.1.14 Reasons Summary

I was pleasantly surprised by the product development firms' answers to why their clients outsource product design. At least some clients may be realizing strategic benefits beyond project risk sharing and market inroads. The reasons given also corroborated what I had suspected – knowledge transfer does take place and can be exploited by the design supplier. The interviews highlighted that if the design supplier benefits from new knowledge gained, the client – the original equipment manufacturer – also gains from the exchange of knowledge and from a better product coming from a smarter design firm.

The many reasons given for outsourcing are indicative of the pressures that create an increased willingness to outsource design by the original equipment manufacturer (OEM). This is represented in a system dynamics diagram in Figure 5-4: Drivers on the OEM Willingness to Outsource Design.

2.2.2 An Ability to Outsource Design

A willingness to outsource and an ability to outsource are not necessarily sequential – they are truly complementary. Converting a willingness to outsource into an ability to outsource requires specific attributes in the product and design process. In other words, does the firm have an available supplier base with the capabilities (or the potential) to deliver the desired product or service as well as the technology and skills necessary to effectively manage the outsourced design? Is the product architecture such that design outsourcing is easy? This section examines how changes in the supplier base, design process and technology, and product architecture

---

[54] Brian J. Matt, Telephone interview with Altitude Inc. (Somerville, MA: March 10, 2000).

contribute to creating an ability to outsource design. When this ability is combined with a willingness to outsource design, the trend to outsource design will grow.

2.2.2.1 Contributions from Changes in the Design Supplier Base

Design outsourcing is only possible if a company is able to find another firm willing to perform the service. With the expansion of services offered by product development firms and the growth, in general, of outsourcing in the 1990s, companies are able to find willing suppliers to take on the design of their products.

Contract manufactures have also stepped in to accept the increased demand for design services. For example, Solectron Corporation is not only a rapidly growing electronics contract manufacturer, it also exploits its ties to the Silicon Valley to design products. Sometimes those products are for competitors.[55] In the auto industry, the original equipment manufacturers of the auto industry are forcing design to be performed by their tier one suppliers, who in turn force their suppliers to do design.

Product Genesis and Herbst Lazar Bell described the difficulty most product development firms have competing against firms that are willing to give away the design of the product to get a guaranteed manufacturing contract.[56] Supporting this viewpoint is 9th Wave, which already has some manufacturing capability, who said that their clients love the fact that they can provide a one-stop service for a new product.[57]

The combination of one-stop shopping for product design and manufacturing aligns exactly with the kind of strategic questions I asked earlier. Can a product-based company that unbundles and outsources these elements of its value chain sustain competitive advantage? What elements of a company's value chain are critical for competitive advantage?

2.2.2.2 Contributions from Changes in Product Architecture

Product modularity is also an enabler for design outsourcing as alluded to in paragraph 2.2.1.12 Reasons Related to Product Architecture. The architecture-based ability to outsource reinforces the willingness to outsource as shown in Figure 2-5: Expanded System Dynamics

---

[55] Scott Thurm, "Solectron Becomes a Force in 'Stealth Manufacturing,'" Wall Street Journal (August 18, 1998).
[56] Anthony Pannozzo, Interview at Herbst Lazar Bell (Waltham, MA: March 10, 2000) and Brian Vogel, Interview at Product Genesis (Cambridge, MA: March 6, 2000).
[57] Ed Gilchrest, Interview at 9th Wave (Southbury, MA: March 4, 2000).

Model of Product Modularity on Design Outsourcing. In essence, the more modular the design, the more feasible it is to separate a component to be developed externally. The new positive, or reinforcing feedback loop representing this occurrence is labeled Mass Customization Loop II. Of course, the significant delays in this system that are tied to the product development cycle and product lifecycle are not represented in this top-level diagram.

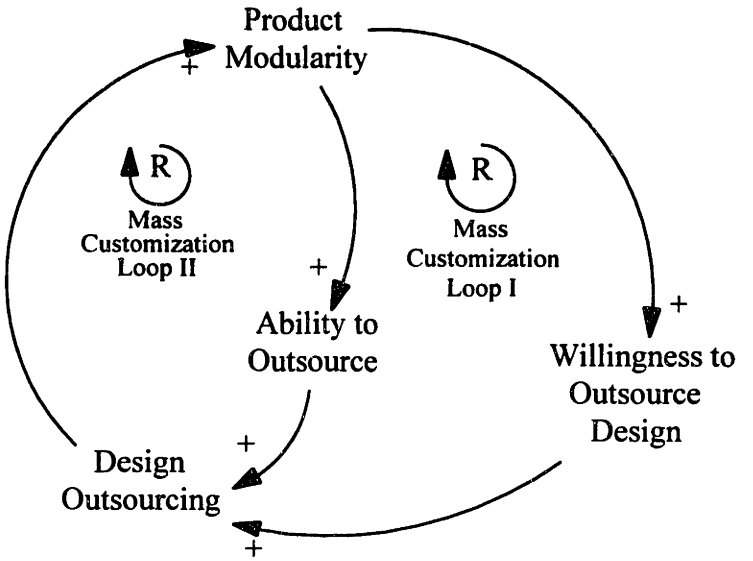

Figure 2-5: Expanded System Dynamics Model of Product Modularity on Design Outsourcing

2.2.2.3 Contributions from Changes in the Design Process and Technology

Design technology and process changes have changed the ability to outsource design in parallel with affecting the willingness to outsource design. For example, companies have embraced the benefits of product development teams and their ability to generate better performing products with fewer post-design phase changes. To enhance team communication and effectiveness, companies collocated their team members. Today's technology improves the ability to communicate among design teams even when they are not collocated, making the decision to outsource design less difficult. Computer models of parts can be easily mailed electronically between the product development firm and the client. When companies are linked to one another in an electronic data interchange network, central shared storage is possible. Web technology is enabling this capability, as well, via extranets, where a private network using Internet protocols provides secure data exchange between businesses.

As technology advances, the communication barriers to design outsourcing will erode further. And, as communication improves across borders, so does the ability to transfer knowledge.

2.3 Chapter Summary

This chapter has supported my original perception that design outsourcing is a growing phenomenon. Through interviews with six different product development firms and my own design experience, I have postulated 13 contributors to a firm's willingness to outsource their design and three contributors to the ability to outsource design. The interviews changed my original perception of design outsourcing by providing a view into the potential benefits of this practice. Design as a process has changed to become more collaborative and thereby intensifying communication among design team members. Technology helps to make that communication easier.

If design is a fertile collection of product knowledge, then increasing the collaboration and communication between the design supplier and the corporation would imply more knowledge would be transferred, both ways. The effects of this transfer would have to be considered strategically. Chapter 3 looks at how knowledge and design are intertwined. The interviews with the product development firms will also provide lessons in how that knowledge can be exploited for greater innovation.

Chapter 3. Knowledge Transfer in Design

Design outsourcing could be a welcomed addition to the options a company has to manage its value chain. In this chapter, I present the unique attributes of design knowledge and why design is an especially effective means of transferring organizational product knowledge. In Chapter 4, these reasons will help identify some of the strategic risks and benefits associated with this practice.

Apart from the obvious function of design – to create new products that become revenue generators for the corporation – an important characteristic of design is its ability to innovate, integrate and transfer knowledge within an organization. When design is outsourced, these properties are outsourced as well. The design supplier can participate in the benefits that might normally fall to the corporation. Earlier, I noted that there is an apparent contradiction in retaining the ability to remain competitive through innovation while outsourcing design. Put into the form of a question, what is the relationship between the design process and product knowledge and why should these be uniquely considered in corporate strategic outsourcing decisions?

As shown in Figure 3-1: Thesis Structure Highlighting Chapter 3 Focus, this chapter examines the characteristics of design that make it a unique source for transferring knowledge. This ability is important internally and an important consideration for design outsourcing.

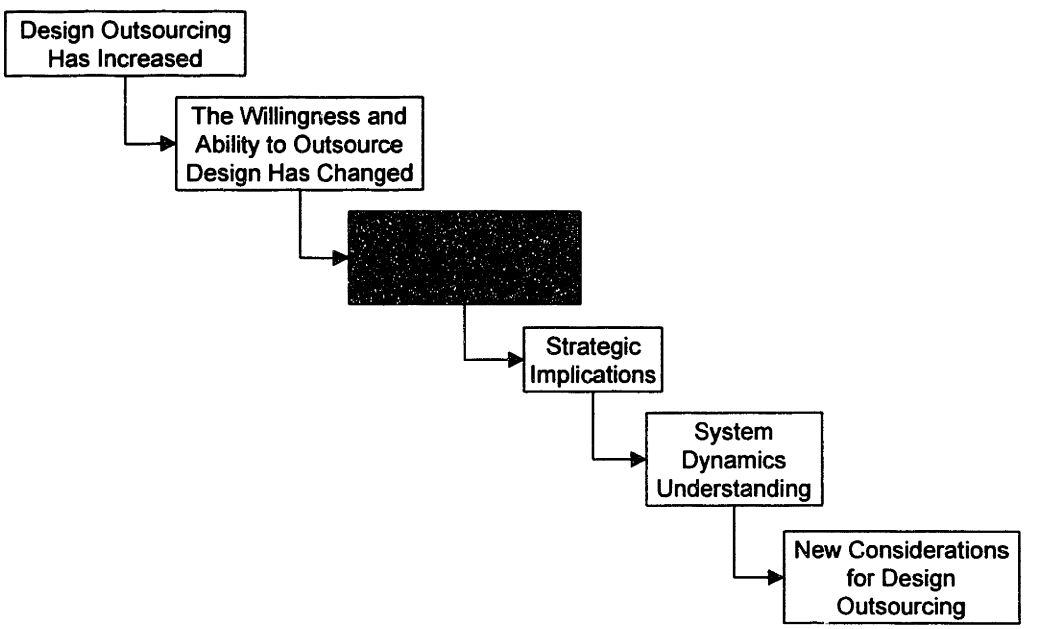

Figure 3-1: Thesis Structure Highlighting Chapter 3 Focus

I will begin by describing the explicit and tacit constituents of design knowledge and how this makeup affects the ability to transfer product knowledge. Problem solving contributes to this knowledge and technology has changed it, making it easier to transfer product knowledge today than was possible ten years ago. Product knowledge content dependencies, such as the problem being solved and the product architecture will be discussed. I will propose that a new construct called "knowledge intensity" be employed for discussing the relative knowledge makeup of products. I will also propose that the idea of a "knowledge kernel" be used as a modifier to Prahalad's and Hamel's "core product"[58] to more poignantly describe the relationship of knowledge and a company's core competency. In the more detailed discussion of how design knowledge is transferred, knowledge intensity and knowledge kernels will help solidify the relationship between design and product knowledge transfer. The interviews with the product development firms provide additional bolstering of the argument that knowledge transfer does take place during design and that the design supplier does use this knowledge. The building of this chapter towards knowledge transfer in design is outlined schematically in Figure 3-2: Schematic of Chapter 3 Outline.

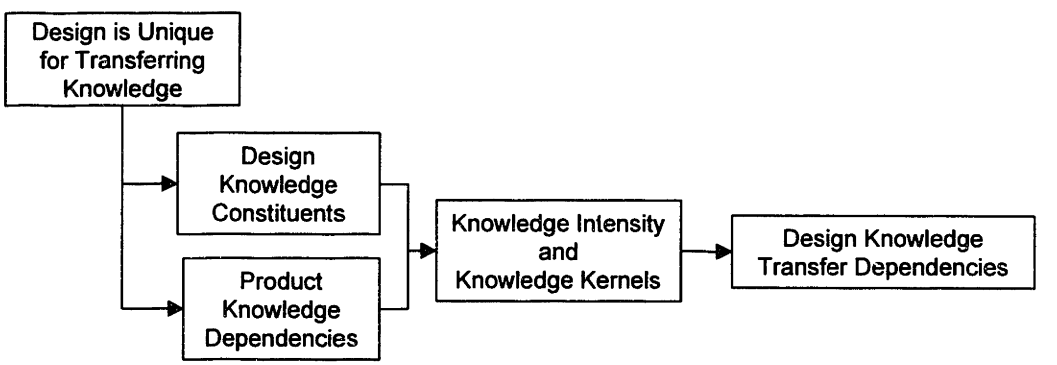

Figure 3-2: Schematic of Chapter 3 Outline

3.1 Design Knowledge Constituents

I have conveyed that there is some tension that normally exists in the outsourcing of a product design because of the transferring of knowledge that normally takes place in this process. To better understand the sources for this tension, one might ask, "What is knowledge?" Leonard defines knowledge as "information that is relevant, actionable and at least partially based on

[58] C. K. Prahalad and Gary Hamel, "The Core Competence of the Corporation," Harvard Business Review 68 (May-June 1990), pp. 79-90.

experience."[59] Davenport and Prusak contend that "knowledge is a fluid mix of frames experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information."[60] As one might have intuitively judged, knowledge is more than just information or data. Having knowledge implies an ability to use that knowledge under the right conditions – it is actionable, implying a strategic importance.

Knowledge about a product is different than knowledge about the design of the product. Design knowledge includes not only the product knowledge – its material, its function, its assembly – but also what tradeoffs were made between different attributes like manufacturing ease and greater performance, how these tradeoffs were made and why certain features were integrated in a particular fashion. It provides the answers to why a product is designed in a particular way.

3.1.1 Explicit Knowledge and Tacit Knowledge

Explicit knowledge -- codified or capable of being codified – includes standards and specifications, analysis methods, drawings, documented procedures and technology. Except for brand new technology and intellectual property, the explicit knowledge in a design rarely holds significant competitive value. A chief engineer responding to Kimzey's outsourcing study survey reinforced this perspective by stating, "we do not believe we can get a lock on technology to the exclusion of competitors."[61]

The same cannot be said for tacit knowledge. By its very nature, tacit knowledge is difficult to communicate, making it harder to imitate. When I was fresh out of undergraduate school working on a new part for a fixed-wing fighter under the guidance of an experienced lead engineer, he made some suggestions to my design that were clear afterwards would improve the part. The changes were structurally subtle, but enhanced the overall appearance and performance of the part. When I asked how he knew that those changes were right before any analysis was

---

[59] Dorothy Leonard, Class notes from Harvard Business School Course 2170: The Knowledge Lab (September 8, 1999).

[60] Thomas H. Davenport and Laurence Prusak, Working Knowledge: How Organizations Manage What They Know (Boston, MA: Harvard Business School Press, 1998), p. 5.

[61] Charles H. Kimzey, Jr., "Outsourcing Technology for New Product Development: A U.S.-Japan Study of Technology Strategy," Ph.D. Dissertation in Management of Technology, (Nashville, TN: Vanderbilt University, 1998), p. 186.

done, he gave me an answer that is a reflection of the tacit element in design knowledge. He said, "If it looks right, it is right." Obviously, his idea of right and mine were very different. His years of experience and an extensive knowledge foundation had given him an ability to quickly judge and act on subtleties in design that I had not yet developed.

3.1.2 Problem Solving and Systems Integration Contributions

The design of a product is an exercise in blending both tacit and explicit knowledge to solve a problem. Or, as Jim Bleck of Bleck Design Group said, "The essence of design is making decisions."[62] Ed Gilchrest from 9th Wave noted during our conversation, the real asset "is the knowledge in the designer's head."[63] In other words, the knowledge that is codified or explicitly represented by a product is not as valuable as everything else the designer knows. The designer knows about the "why" and "how" of solving the design problem as well as the final answer. When the next design problem is presented, the designer may not be able to apply the same answer, but may very well be able to expertly apply the learned methods and reasons to creatively find a new answer. In reference to Bohn's eight stages of knowledge, ranging from complete ignorance (stage one) to complete knowledge (stage eight), when the most important knowledge is in the workers' heads, knowledge is at stage one or two – it is expertise based.[64]

The complexity of many of today's technology products requires the input from people from many different disciplines to be integrated into a final solution. These product development teams are a "fusion" of different ideas working on the same problem, which ultimately is a major source of knowledge.[65] Therefore, design knowledge is not just in the designer's head, but also in the heads of all those who helped in the integration of the solution.

The integration of many different requirements and technologies into a single product can be the significant differentiator between a successful and a poor product. Iansiti points out in his study of technology integration in the computer industry that the integration choices made during design and not the technologies selected can determine success. In one case, the overall system

---

[62] Jim Bleck, Interview at Bleck Design Group (Chelmsford, MA: March 8, 2000).
[63] Ed Gilchrest, Interview at 9th Wave (Southbury, MA: March 4, 2000).
[64] Roger E. Bohn, "Measuring and Managing Technological Knowledge," Sloan Management Review 36 (Fall 1994), pp. 61-73.
[65] Thomas H. Davenport and Laurence Prusak, Working Knowledge: How Organizations Manage What They Know (Boston, MA: Harvard Business School Press, 1998), p. 49-50.

performance of two mainframe processors was compared along with their fundamental component technologies. One processor achieved significantly better performance despite 10 of its 12 fundamental technologies being worse and the remaining two on par with the other processor. Better integration decisions were made by the first firm to develop a faster processor with poorer technologies.[66] Iansiti later shows how technology integration is an enabler for an organization to "view the entire product and production systems as a coherent whole, balancing the potential of individual technologies with the requirements of the context of application."[67]

3.1.3 Technology Contributions to Content

Today's design and engineering software and hardware enables a large complex integrated system, such as a commercial aircraft or navy submarine, to be designed and analyzed in a virtual three-dimensional, solid-geometry computer environment. Entire manufacturing processes and factory flows can be simulated directly from the design models. Embedded within the computer models are data linked back to knowledge-based engineering software used to conceive the design and links to master lofted surfaces that span many parts. With the latest application releases, critical dimensions and tolerances can be portrayed in three-dimensional space. Changing the shape, or parameters, of a design feature can be quickly propagated through the computer model to modify any related features.[68] In addition to these links, some high technology system integrators are employing Knowledge-Based Engineering (KBE) programs using object-oriented software languages. These computer applications contain the codified knowledge of engineers and designers. They interface with the computer-aided engineering (CAE) programs to speed design development and geometry creation.

In addition to changing how designers work, technology advancements have changed the knowledge intensity of their output. Computer-aided two-dimensional drafting files contained little more knowledge than what was on a drawing. Today, a computer model's three-dimensional, solid-geometry, parametric representations with links to enterprise-wide databases and other design models mean it contains much more actionable knowledge about the product

---

[66] Marco Iansiti, Technology Integration: Making Critical Choices in a Dynamic World, (Boston, MA: Harvard Business School Press, 1998), pp. 79-81.
[67] Ibid., p. 119.
[68] CATIA web site, http://www.catia.com.

and the design than it once did. As a result, the ability to learn from these models has been increased. Product Insight noted that they learn a great deal about the clients' products from their clients' three-dimensional computer models.[69]

The interviewed product development firms described how the Internet and effective search engines have made design research simpler, faster and more productive, widening their sources of design knowledge for possible inclusion in the product.

3.2 Knowledge Intensity and Knowledge Kernels – a New Construct

To facilitate the discussion of how knowledge is embodied by a product and the strategic implications of doing so, I offer two new terms: knowledge intensity and knowledge kernels. Their meanings are discussed in the following paragraphs.

3.2.1 Knowledge Intensity

I propose a construct for relatively measuring the knowledge that is embodied by a product – knowledge intensity. Knowledge intensity is directly related to the amount of tacit and explicit knowledge combined into the product to solve its peculiar design problem in a unique and attractive way. Knowledge intensity is not a design evaluation – how well it fulfills its intended purpose. Nor is it a measure of uniqueness. Knowledge intensity is intended to be a relative concept that enables discussion of product knowledge investments as well as a relative measure of the amount of knowledge that could be transferred during design outsourcing. When a company is considering outsourcing the design of a product, working through a knowledge intensity discussion will help identify what domains of knowledge are invested in the product design.

Borrowing from Davenport and Prusak, knowledge intensity summarizes the depth and breadth of "experience, values, contextual information, and expert insight"[70] that had to be developed, searched, sorted, sifted, integrated and applied to become the design of a product or product component. The bar graph shown in Figure 3-3: Relative Knowledge Intensity for Various Products is a qualitative judgement of knowledge intensity for different products.

---

[69] Telephone interview with Product Insight (Acton, MA: March 8, 2000).

[70] Thomas H. Davenport and Laurence Prusak, Working Knowledge: How Organizations Manage What They Know (Boston, MA: Harvard Business School Press, 1998), p. 5.

Being knowledge intensive is not synonymous with being complex. For example, a helicopter rotorblade might appear simple compared to the mechanical and electrical complexity of a modern automobile powertrain. However, the rotorblade integrates decades of empirical and theoretical knowledge about aerodynamics, materials and structures, load analysis in static and dynamic environments, acoustics, vehicular performance and control, manufacturing processes, nondestructive testing and life-cycle costs. This breadth and depth of knowledge is then rendered into a physical form through the cutting, shaping, molding, bonding, sanding and painting of advanced materials. While the rotorblade appears simple, its knowledge intensity is qualitatively of the same magnitude as the automobile powertrain.

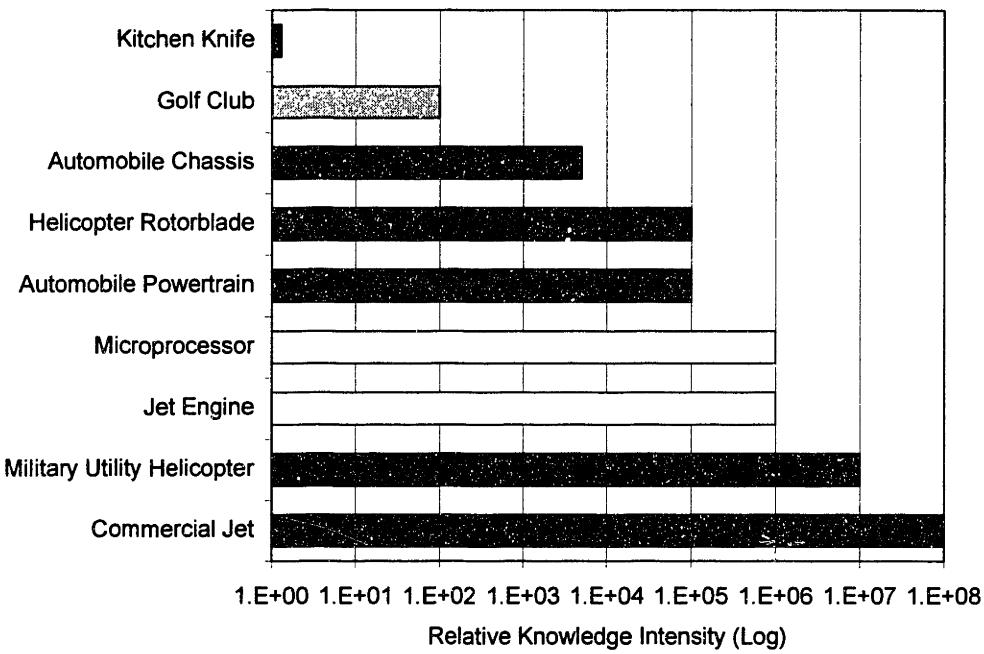

Figure 3-3: Relative Knowledge Intensity for Various Products

The knowledge intensity of one product may be very different than that of another similar product. For example, the OXO International Good Grips kitchen utensils have a soft wide handle that was originally designed to make them easier for arthritic elderly cooks.[71] The unique handle design has spawned an entire line of successful utensils. An OXO knife (see Figure 3-4: OXO International Good Grips Utility Knife with Ergonomic Handle) would be higher in

[71] "A Decade of Design: How Great Products Can Boost The Bottom Line," Business Week (November 29, 1999), p. 90.

knowledge intensity than a competing generic knife without these ergonomic features because the OXO product embodies greater knowledge.

Figure 3-4: OXO International Good Grips Utility Knife with Ergonomic Handle[72]

Along with the degree of integration that is required to bring together different technologies, another factor influencing the knowledge intensity of a product is the amount of product testing and support required to develop the product or the technology within the product. For example, a laptop computer for use in the field by military personnel will undergo unique and rigorous testing compared to a laptop computer used for the home or office. Testing might include adverse weather or electrical conditions. The results of the testing during product development will flow back into the product as design improvements before production begins. Therefore, the military laptop would be more knowledge intensive than the home or office laptop.

After the product has been in use and information comes back from testing and after-sales support, this information also adds to the knowledge intensity of its succeeding products. Schematically, knowledge intensity influences are shown in Figure 5-3: Collaboration and Knowledge Intensity Influences.

3.2.2 Knowledge Kernels

While knowledge intensity is intended to convey a sense of how much knowledge is embodied in a product, the knowledge kernel is that part or product that embodies the knowledge that is core to the corporation. I prefer the emphasis that the phrase "knowledge kernel" places on the role of knowledge to the "core product" idea put forward by Prahalad and Hamel. Core products are "the physical embodiments of one or more core competencies."[73] The idea of a knowledge kernel properly emphasizes what might be lost or gained during design is outsourcing. It forces one to address the concept of outsourcing knowledge.

---

[72] OXO web site: http://www.oxo.com.

[73] C. K. Prahalad and Gary Hamel, "The Core Competence of the Corporation," Harvard Business Review 68 (May-June 1990), p.85.

An example of a knowledge intensive product with a knowledge kernel is a commercial jet aircraft made by Boeing. The aircraft requires the integration of many tested complex systems, materials and technologies. The knowledge kernel for Boeing is the wing, because despite the large number of partners and suppliers that design and build parts for Boeing's aircraft, the wings are designed and built by Boeing.[74] The wing represents the unique knowledge built by Boeing to create a high-performance commercial aircraft.

In the auto industry, the automobile knowledge kernel has traditionally been the powertrain. In a recent interview with a panel of top suppliers to the auto industry, the panelists concluded that suppliers will be playing a much larger role in powertrain development. Consider the remark: "The control of the powertrain is where you see the outsourcing. Today in Europe, we do complete engine-management systems. Now the U.S. OEs [Original Equipment manufacturers] are starting to say, 'Try to do that.'"[75]

Today it is unimaginable to think of Honda outsourcing the design of its engines, the knowledge kernel inside its products. Honda's expertise in engines has been a trademark of its successful expansion into multiple markets, including automobiles, lawnmowers, and generators.[76]

For the clients that the interviewed product development firms work with, the knowledge kernel is frequently software. This is typically the part of the product which firms have been reluctant to disclose to the design firm. Their hesitance is an acknowledgement of the competitive advantage they expect to reap from this knowledge kernel and the knowledge transfer that takes place when it is outsourced.

It is possible to expand this concept further and think of multiple tiers of knowledge kernels. For example, if the engine is the knowledge kernel for an automobile, what specific knowledge domain within the design of the engine is the kernel for the engine? But this layering should be done with caution, lest important integrative elements of the product be misconstrued as not worthy of significant investment.

---

[74] Thomas E. Pinelli, Rebecca O. Barclay, John M. Kennedy, and Ann P. Bishop, Knowledge Diffusion in the U.S. Aerospace Industry: Managing Knowledge for Competitive Advantage, Part A (Greenwich, CT: Ablex Publishing, 1997).

[75] "Suppliers Expect Bigger Role in Powertrains," Automotive News (August 3, 1998), p. 141.

[76] Gary Hamel and C. K. Prahalad, Competing for the Future (Boston, MA: Harvard Business School Press, 1994).

3.3 Design Knowledge Transfer Dependencies

The varying knowledge content in a product design is one factor that will influence the quantity of knowledge that can be transferred. The extent of knowledge that is transferred is a function of the collaboration and communication that takes place.

3.3.1 Integration and Collaboration

The integration of many different types and sources of knowledge in the context of a specific design problem is a significant contributor to a product's knowledge intensity, which in turn, influences the degree of collaboration required for its completion. All other factors being equal, as the knowledge intensity of the product increases, the amount of collaboration necessary increases. Ultimately, collaboration, of which communication is a part, is the knowledge transfer instigator between the supplier and the corporation. This relationship is shown schematically in Figure 5-3: Collaboration and Knowledge Intensity Influences.

As an example of how integration can influence the collaboration and knowledge transferred, consider the design of a fairing to enclose the radar on an aircraft. Designing this product requires the integration of knowledge about materials and processes, structural analysis, weight analysis, aerodynamic flow, electromagnetic behavior, manufacturing processes (including cost), joint and attachment configurations, maintenance procedures, and potential damage scenarios (such as bird strike or lightning strike). Most of this knowledge is codified in many different forms but how and why to select the various types of knowledge and integrate it, is the uncodified designers' job. When the fairing is complete and installed on an aircraft, its external simplicity belies the knowledge intensity resulting from this complex design integration. If the design of such a fairing is outsourced, integration knowledge necessary for the design will be transferred through the interactions of the corporation and the supplier. Sufficient collaboration must occur for the corporation's needs to be understood by the design supplier for design execution.

The fairing design example also points out the impact of modularity on knowledge transfer. If so desired by the company, the fairing design could be outsourced with an outer defined surface, a mating interface definition, a weight and cost limit, impact requirements and electromagnetic requirements. Less knowledge about the rest of the aircraft would then be

transferred to the supplier. However, for the corporation to develop this information requires sufficient specific knowledge and systems integration skills.

The product development firms recognize that knowledge transfer takes place both ways during product design collaboration. Product Genesis said this transfer begins with the initial interaction between the client and the firm.[77]

3.3.2 Communication

Communication during design collaboration is the fundamental means of transferring knowledge. Communication must occur in some form – written, oral, computer files. Communication and effective knowledge transfer are influenced by having a common language, collocation and trust building, the use of boundary objects and design process technology.

3.3.2.1 Common Language

"[I]t is hard to transfer the full complexity of a technology. . . . If the receptor knows very little, he can do very little even with the simple idea, because he cannot generate the mass of detail that is required to put it into execution. On the other hand, if he knows a great deal and is capable of generating the necessary details, then from just a few sentences or pieces of technology he will fill in all the rest. That is why it is hard to transfer technology to the Third World and very hard not to transfer it to Japan."[78]

This commentary on Japan's ability to quickly grasp and then employ new technology knowledge from the U.S. is also a commentary on an important knowledge transfer lubricant. In simple terms, the more similar the knowledge that two people have within a knowledge domain, the more easily knowledge from the domain can be transferred between them. Davenport and Prusak also observed that a major factor in effective knowledge transfer is a common language of about the knowledge domain. Without this commonality, trust and understanding will not be possible.[79]

---

[77] Brian Vogel, Interview at Product Genesis (Cambridge, MA: March 6, 2000).

[78] Dorothy Leonard, Wellsprings of Knowledge: Building and Sustaining the Sources of Innovation (Boston, MA: Harvard Business School Press, 1998), p. 215. Quote attributed to Ralph Gomory, "Technology Development," Science 220 (1983), pp. 576-580.

[79] Thomas H. Davenport and Laurence Prusak, Working Knowledge: How Organizations Manage What They Know (Boston, MA: Harvard Business School Press, 1998), p. 98.

In a case study looking at how knowledge transfer could be facilitated between a contracting company and a supplier, Tunisini and Zanfei found that the first investment that had to be made was the skill-intensive and time-consuming process of developing a shared language.[80] Product Genesis reinforced this finding by saying that the key to knowledge transfer was the language used. When they embark on a new product development engagement with a client, Product Genesis ensures that all participants understand a glossary of project-specific terms.[81]

3.3.2.2 Collocation and Trust Building

The contributions of physical location to knowledge transfer have been identified in works by Tyre and Hippel[82], and Davenport and Prusak.[83] In the 1980s, when the practice of "throwing it over the wall" began to come to a close with the implementation of product development teams, it was discovered that moving the team members together facilitated communication and learning by the team. The tacitness of product design knowledge is fundamentally why face-to-face communication has been especially important in ensuring knowledge "blending." A byproduct of collocation is improved trust. As individuals work together, they are able to build a rapport that facilitates knowledge transfer.[84]

The classic examination of communication within an organization done by Allen reveals why collocation for a product development team has traditionally been viewed as critical to effective team interaction and product success. Allen showed that the frequency of communication between individuals belonging to the same organization (such as a product development team) dropped significantly when the physical distance separating them was greater than 30 meters (98 feet) (see Figure 3-5: Communication Frequency versus Separation Distance).[85]

---

[80] Annalisa Tunisini and Antonello Zanfei, "Exploiting and Creating Knowledge Through Customer—Supplier Relationships: Lessons From a Case Study," R&D Management 28 (1998), p. 117.

[81] Brian Vogel, Interview at Product Genesis (Cambridge, MA: March 6, 2000).

[82] Marcie J. Tyre and Eric von Hippel, "The Situated Nature of Adaptive Learning in Organizations," Organization Science, 8 (1997 Jan-Feb), pp. 71-83.

[83] Thomas H. Davenport and Laurence Prusak, Working Knowledge: How Organizations Manage What They Know (Boston, MA: Harvard Business School Press, 1998), pp. 99-100.

[84] Ibid., p. 100.

[85] Thomas J. Allen, Managing the Flow of Technology: Technology Transfer and the Dissemination of Technological Information with the R&D Organization (Cambridge, MA: MIT Press, 1977).

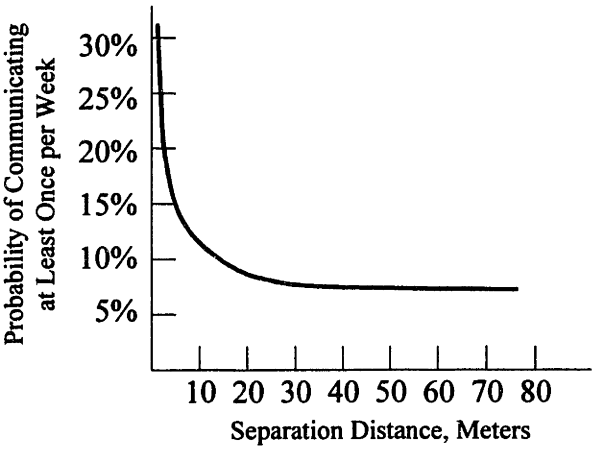

Figure 3-5: Communication Frequency versus Separation Distance[86]

Because personal communication is an essential part of tacit knowledge transfer, collocation would seemingly be critical to knowledge transfer between designers.[87] Davenport and Prusak suggest one way to ensure corporate success is to "hire smart people and let them talk to one another."[88] Paragraph 3.3.2.3 Boundary Objects and Technology discusses how technology has altered the need for collocation.

However, as Davenport and Prusak point out, just giving people the opportunity to talk to one another does not directly imply that knowledge will be transferred. Supplemental methods for encouraging design-focused knowledge discussions are needed.[89] Boundary objects used in a product development team (PDT) environment facilitate these discussions.

3.3.2.3 Boundary Objects and Technology

Boundary objects, proposed by Paul Carlile from his work on product development teams, are physical representations that help solidify problem definition and focus discussion. Noehren furthered Carlile's work by showing that there was a statistically significant correlation between the frequency of boundary object usage by a product development team and the success of the project. Noehren also developed a Boundary Object Richness Scale showing three-

---

[86] Thomas J. Allen, Managing the Flow of Technology: Technology Transfer and the Dissemination of Technological Information with the R&D Organization (Cambridge, MA: MIT Press, 1977).

[87] Thomas H. Davenport and Laurence Prusak, Working Knowledge: How Organizations Manage What They Know (Boston, MA: Harvard Business School Press, 1998), p. 95.

[88] Ibid., p. 88.

[89] Ibid., p. 95.

dimensional boundary objects provide a more effective product development team communication focus than two-dimensional drawings.[90]

The effectiveness of a boundary object in communicating knowledge about a design is a consideration in the outsourcing of design. As described in paragraph 3.1.3 Technology Contributions to Content, technology has changed the ability of designers to communicate through computer models and virtual three-dimensional representations. With manual drafting and drawings, the knowledge of the design resided in the designers' and analysts' minds. The drawing was a mute device for communicating a fraction of the knowledge about the product. Today's three-dimensional computer models communicate much greater knowledge about the product. Web-enabled design applications, such as Dassault Systeme's CATIA CATWeb Navigator for 3D now facilitate design collaborations around the world over the Internet.[91]

Another change pointed out by the product development firms is the ability to create rapid prototype models directly from the computer model of the product. Several of the firms stated their desire to quickly get a three-dimensional model of the design to the client. They recognize intuitively that the prototype is an effective means of communicating knowledge about the design – it is a better boundary object. When prototypes are combined with virtual simulations made possible through advanced software linked to the engineering model, knowledge about the configuration, behavior and functioning of a product made available to the knowledge receiver is extensive.

The interviewed product development firms endorsed the changes in their processes made possible by the Internet and electronic mail, enabling rapid transmission of computer models. Ulrich and Eppinger have seen electronic mail and voice mail foster informal communication among people whom already know one another, removing barriers that physical separation creates.[92]

---

[90] William L. Noehren, Development and Empirical Investigation of a Boundary Object Richness Scale for Product Development Teams, Masters Thesis, Alfred P. Sloan School of Management, Massachusetts Institute of Technology, June 1999. Paul R Carlile's work attributed to: "Understanding Knowledge Transformation in Product Development: Making Knowledge Manifest Through Boundary Objects", Business Administration, University of Michigan, 1997.

[91] CATIA web site, http://www.catia.com.

[92] Karl T. Ulrich and Steven D. Eppinger, Product Design and Development (McGraw-Hill, Inc., 1995), p. 275.

3.4 Knowledge Depletion and Loss

One of the unique attributes of knowledge compared to other corporate assets is that it easily can walk out the door. People and the knowledge they have leave an organization for a number of reasons. Design knowledge is no different form other knowledge except that the tacit content of design makes attempts to codify it before it is out the door more difficult. Leonard offers a definition for knowledge management as "the collection of processes that govern the creation, dissemination, and utilization of knowledge to fulfill organizational objectives."[93] Knowledge management practices in the corporation can help prevent knowledge depletion and loss by ensuring knowledge is disseminated and reused.

In her study of the knowledge management model Chaparral Steel, Leonard recalls the story of Chaparral's movement into near net shape steel beam casting. A key enabler for this new process was an innovative mold. Although mold suppliers were tapped for expertise, the design was done in-house by Chaparral's own specialist. The reason given by the company was "To keep the knowledge here."[94] Chaparral recognized that future refinement of the process was dependent on having the basis of knowledge from the design in-house.

For knowledge to be effective, it must be integrated and applied.[95] Or, more simply, use it or lose it. Stating that design knowledge exists in an organization is actually a static assessment. An organization is dynamic with people coming and going. Knowledge is also dynamic, changing and advancing through innovation and experience. Without continually refreshing its design knowledge through new projects, especially in technology areas, a corporation will not be able to effectively compete with new, internally generated innovative designs. By not participating in new designs and practicing or testing its knowledge, an organization will be depleted and eventually lose its design knowledge. The knowledge intensity of the product will partially determine the delay associated with draining this stock of knowledge.

---

[93] Dorothy Leonard, "Glossary of Terms" distributed class material from Harvard Business School Course 2170: The Knowledge Lab (September 8, 1999). Definition is attributed to pan-European research conducted by Cranfield School of Management, Cranfield, U.K.

[94] Dorothy Leonard, Wellsprings of Knowledge: Building and Sustaining the Sources of Innovation (Boston, MA: Harvard Business School Press, 1998), pp. 20-21.

[95] Marco Iansiti, Technology Integration: Making Critical Choices in a Dynamic World, (Boston, MA: Harvard Business School Press, 1998), p. 24.

One of the ramifications of design knowledge depletion is the need to find additional sources for the required knowledge as discussed in Chapter 2. This can become a reinforcing feedback loop leading to further skill and knowledge erosion as shown in Figure 5-10: The OEM Knowledge Depletion Reinforcing Loop.

3.5 Chapter Summary

An examination of the knowledge constituents in design identified a high tacit content to go along with design's obvious explicit knowledge content. A product is an embodiment of the tacit and explicit knowledge that is traded-off and integrated during design in a process that naturally employs collaboration. A relative qualitative measure of the amount of knowledge embodied by the product is called its knowledge intensity. Along with an alternative to the concept of a core product called the knowledge kernel, these concepts facilitate the important linking of knowledge and products during strategic outsourcing decisions. The knowledge transferred during design outsourcing collaboration and communication is influenced by having a common language for design discussions, the degree of collocation and trust building, and the use of boundary objects facilitated by design process technology. Knowledge depletion and loss can occur if knowledge is not applied.

In light of the unique qualities of design knowledge, the strategic implications of design outsourcing are examined in the next chapter.

Chapter 4. Strategic Implications for Design Outsourcing

The Wall Street Journal recently wrote, "The future of the company that produces Russia's famous MiG fighter jets has been thrown into doubt by the resignation of six top designers. Industry analysts say it could irreparably harm the company as it struggles to redefine itself in a period of plummeting orders from the cash-strapped Russian air force."[96] In any company that is product-based, one might ask what would happen if it were to lose its ability to design products.

As shown in Figure 4-1: Thesis Structure Highlighting Chapter 4 Focus, this chapter examines how the corporation may be affected by design outsourcing. The strategic implications are drawn from the uniqueness of design knowledge and knowledge transfer during design. Not all of the implications are detrimental to the corporation. As I learned in the interviews with the product development firms, the same considerations also provide scenarios that can provide great benefits to the corporation. But the uniqueness of the design process makes the decision to outsource more strategically significant than simple make-buy frameworks.

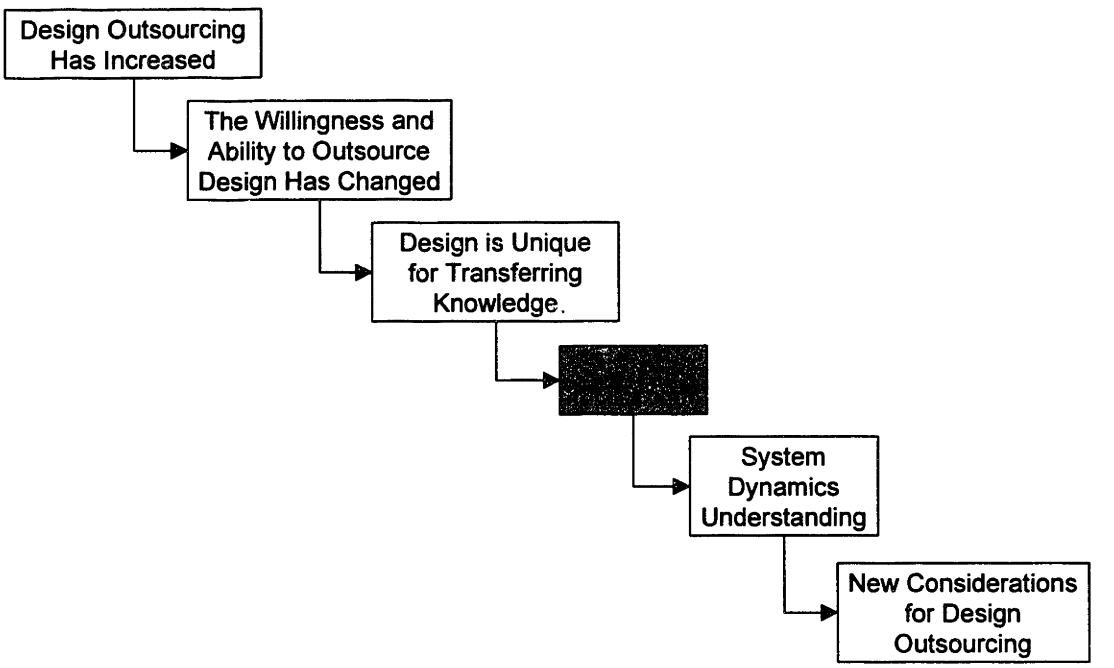

Figure 4-1: Thesis Structure Highlighting Chapter 4 Focus

Because design outsourcing decisions are really decisions about the core competence of the corporation, this chapter will first provide a quick foundation for this concept before exploring the risks and benefits from design outsourcing. The interviews with the product development firms helped to gain a deeper insight into these implications. Afterwards, the dependencies or modifiers to these risks and benefits are explored. For example the knowledge intensity of the product will influence the knowledge that is being transferred during design collaboration, as will the degree of integration required. A schematic of this chapter's construction is represented in Figure 4-2: Schematic of Chapter 4. In Chapters 5 and 6, a system dynamics perspective will help structure what has been learned and then make recommendations on how to apply this learning, respectively.

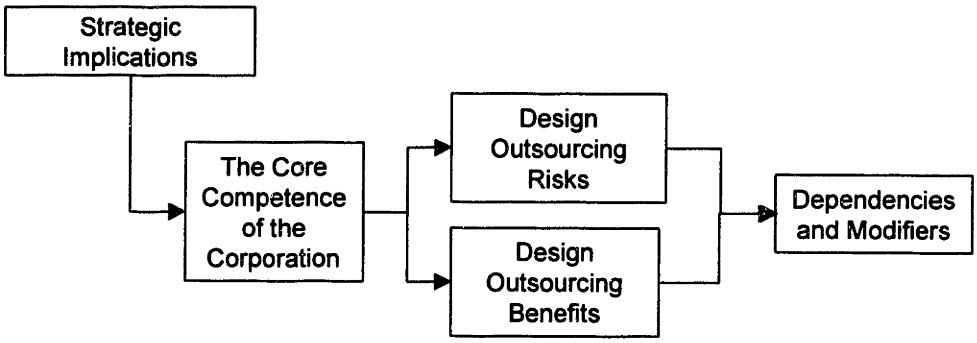

Figure 4-2: Schematic of Chapter 4

4.1 The Core Competence of the Corporation

Prahalad's and Hamel's seminal work, "The Core Competence of the Corporation"[97] on how to compete in the 1990s has altered the business strategy landscape and how corporations think about their business. According to the authors, knowing and fostering the corporation's competencies is the key to long-term sustainable competitive advantage. A core competence is not just something a company does well, or a product that sells well, it represents "collective learning in the organization, especially how to coordinate diverse production skills and integrate

[96] Guy Chazan, "Six Top Designers Quit Russia's MiG Jet Maker: Future Is in Doubt At State-Owned Aircraft Exporter," Wall Street Journal (December 2, 1999), p. A17.

[97] C.K. Prahalad and Gary Hamel, "The Core Competence of the Corporation," Harvard Business Review 68 (May-June 1990), pp. 79-90.

multiple streams of technologies."[98] As businesses have sought to recreate themselves around a core competency, the business landscape has been transformed.

The mergers, acquisitions and diversification brought about in the 1980s were replaced in the 1990s with divestment, focus and outsourcing of non-core businesses. Corporations changed their thinking from owning a portfolio of businesses to owning businesses that augmented their own core competence. Internal operations which were considered not core, such as manufacturing, have been outsourced, creating new business opportunities for operations as diverse as contract manufacturers, legal firms, administration and design, while providing bottom line benefits to the corporation.

The relationship between the core competence of the corporation and outsourcing is at the root of exploring the strategic implications from design outsourcing. Because acquiring, developing and maintaining a core competence requires significant focused investment over time, outsourcing an activity in its entirety is an indication that management does not consider it to be a core competence.

For a company whose livelihood depends on the sale of its products, coming to the conclusion that the design of its products is not core logically implies that it has some other product related skill it does believe is a core competence. In one example, a company may be especially skillful at identifying markets and customer needs in those markets. In this case, the company outsources the design and manufacture of products to fulfill those needs and then sells them under its own label. In another example, a company may be especially adept at developing new technologies. It outsources the design and manufacture of the products that employ the technology, outsourcing the design to leverage the integration skills of the product development firms and using intellectual property to protect its products.

4.2 Design Outsourcing Risks

The instigator of this thesis was my perception that there were strategic risks that were not normally examined as part of a corporation's outsourcing. The following paragraphs seek to expose those risks including competition from the design supplier, supplier holdup, not

---

[98] C.K. Prahalad and Gary Hamel, "The Core Competence of the Corporation," Harvard Business Review 68 (May-June 1990), p. 81.

remaining a knowledgeable buyer, the loss of corporate innovation and industry innovation.

4.2.1 Competition from Supplier

In Chapter 1, examples were presented of design suppliers becoming competitors of the design-buying corporation. Because the product development firms are repeatedly exposed to new product ideas and technologies, I thought examining their propensity for forward integration would provide a tip-of-the-iceberg look into this risk. Companies like Solectron Corporation, the large electronics manufacturer that is growing its design capability, provide a greater risk in bringing to market products that compete directly with their original clients' products. These fears may be warranted, based on history. For example, in 1993 National Semiconductor announced an alliance with Novell to solder and sell its own local area network (LAN) boards, thereby competing directly with its LAN chip customers.[99]

4.2.1.1 Indigenous Product Designs

Each of the interviewed product development firms has experience with developing its own product ideas. This is not a surprising result. But these firms pursued in-house projects with different intentions. Herbst Lazar Bell funds "vision projects" for the purpose of taking technologies and applying them creatively. Their intention is to give inspire their designers by giving them a "clean sheet of paper to explore what the future could be."[100]

Altitude and Bleck Design have gone so far as to design and market their own products. However, the experience has been mixed. Because they did the design, contracted for the tooling and then did the marketing, they found that it disrupted their core business. The activity stole resources and focus from their client business, while troubling them with potential conflicts of interest. Bleck Design said that in the future, if they were to pursue another indigenous design, it would license the design instead of doing the entire product development.[101]

In a similar fashion Product Insight, which has its own manufacturing spinoff, foresees producing indigenous product designs, but a contracted supplier would do the marketing. Like Altitude and Bleck Design, they would do the design and manufacture and outsource the

---

[99] Bob Metcalfe, "Forward Integration Looks Like the Latest Trend," Infoworld, 15 (November 8, 1993), p. 63.
[100] Anthony Pannozzo, Interview at Herbst Lazar Bell (Waltham, MA: March 10, 2000).
[101] Jim Bleck, Interview at Bleck Design Group (Chelmsford, MA: March 8, 2000) and Brian J. Matt, Telephone interview with Altitude Inc. (Somerville, MA: March 10, 2000).

marketing to preserve what they see as the important focus. These three firms look at the value chain in a manner that is different from their clients. They want to focus on the design and outsource the downstream activities, while their clients want to focus on the far upstream (technology) or the downstream (marketing and distribution).[102]

Product Genesis said that they do own ideas outside the "field of use" of their clients. This area of intellectual property establishes from what area of similar work Product Genesis will be excluded for a negotiated number of years. They will not do work for themselves or another client in this field for that period of time. Naturally, the client tries to make it as broad as possible and Product Genesis tries to make it as narrow as possible. They have seen a change in the past two years in clients' attitudes about outsourcing "the family jewels" – typically, software for a product (the product's knowledge kernel). Product Genesis believes that the intensity of firm-client collaboration and the sense of ownership that is imparted have eased client's disclosure fears.[103]

With the most established manufacturing capability of the interviewed firms, 9th Wave said that they have a long list of their own product ideas. In addition to using their manufacturing capability as a competitive weapon with other design firms, they also produce their own product designs. Their product specialty is airbeds for hospitals, but interestingly, they believe that an entire market exists for products that are identical, but a little better than other products currently on the market. In the future, their ultimate goal is to have a separate company that just designs and markets indigenously designed products. Although some of their clients have expressed concern about their growing manufacturing capabilities, apparently thinking about potential forward integration risks, in general it has been an attractant to their firm. The greatest conflict for 9th Wave is trying to decide which projects, internal or external, to pursue. Today, the external projects take preference as they try to grow their portfolio and "earn while they learn."[104]

In general, the design firms acknowledged a desire to pursue indigenously designed products. This desire is balanced by the recognition that future business is dependent on their reputation, that they have resource constraints, and/or that a longer-term strategic intent to pursue

---

[102] Telephone interview with Product Insight (Acton, MA: March 8, 2000).
[103] Brian Vogel, Interview at Product Genesis (Cambridge, MA: March 6, 2000).
[104] Ed Gilchrest, Interview at 9th Wave Inc. (Southbury, CT: March 4, 2000).

internal projects requires a greater critical mass. The contract manufacturers that are more frequently doing design along with the manufacturing may already have the critical mass to pursue indigenous designs.

4.2.1.2 Natural Industry Evolution

As an original equipment manufacturer (OEM) outsources more of its value chain, their reliance on suppliers to design and produce grows. The company may redefine its competence to be planning, marketing and distribution. Eyeing an opportunity to grow further, the design and manufacturing suppliers join together (if they are not already the same firm) to directly compete against the OEM using their own indigenously designed and manufactured products. The original company becomes effectively neutered from its original market space until it can find a new design supplier for its products. This scenario is diagrammed in Figure 4-3: Natural Evolution of a New Original Equipment Manufacturer (OEM).

Like cells that divide and pass on their traits to their offspring, the outsourcing of manufacturing and design influences the suppliers. They learn from the corporation about the product, the technology, and the production idiosyncrasies, thereby becoming much more capable of designing and producing the next generation of products. The suppliers learn by doing. As this cycle repeats, if the corporation does not maintain this capability internally with other products, the corporation's ability to perform the same task is diminished. With time dependent on the product life cycle (see paragraph 4.4.6 Industry Clockspeed) and in an attractive market segment, the more powerful supplier can effectively say, "I can reap more economic rent from selling direct to the consumer and I have the ability to do so."

Fine argues for a related type of natural evolution where an industry cycles between an integral product / vertically integrated industry and a modular product / horizontally integrated industry, creating a "double helix" dynamic cycle. The pressure from niche competitors helps to unbundle a vertical value chain leading to greater modularity and a horizontal industry. In time, supplier power, technical advances and proprietary system profitability create pressure for the integration of the industry bringing it back to its origination point.[105]

---

[105] Charles H. Fine, Clockspeed: Winning Industry Control in the Age of Temporary Advantage (Reading, MA: Perseus Books, 1998).

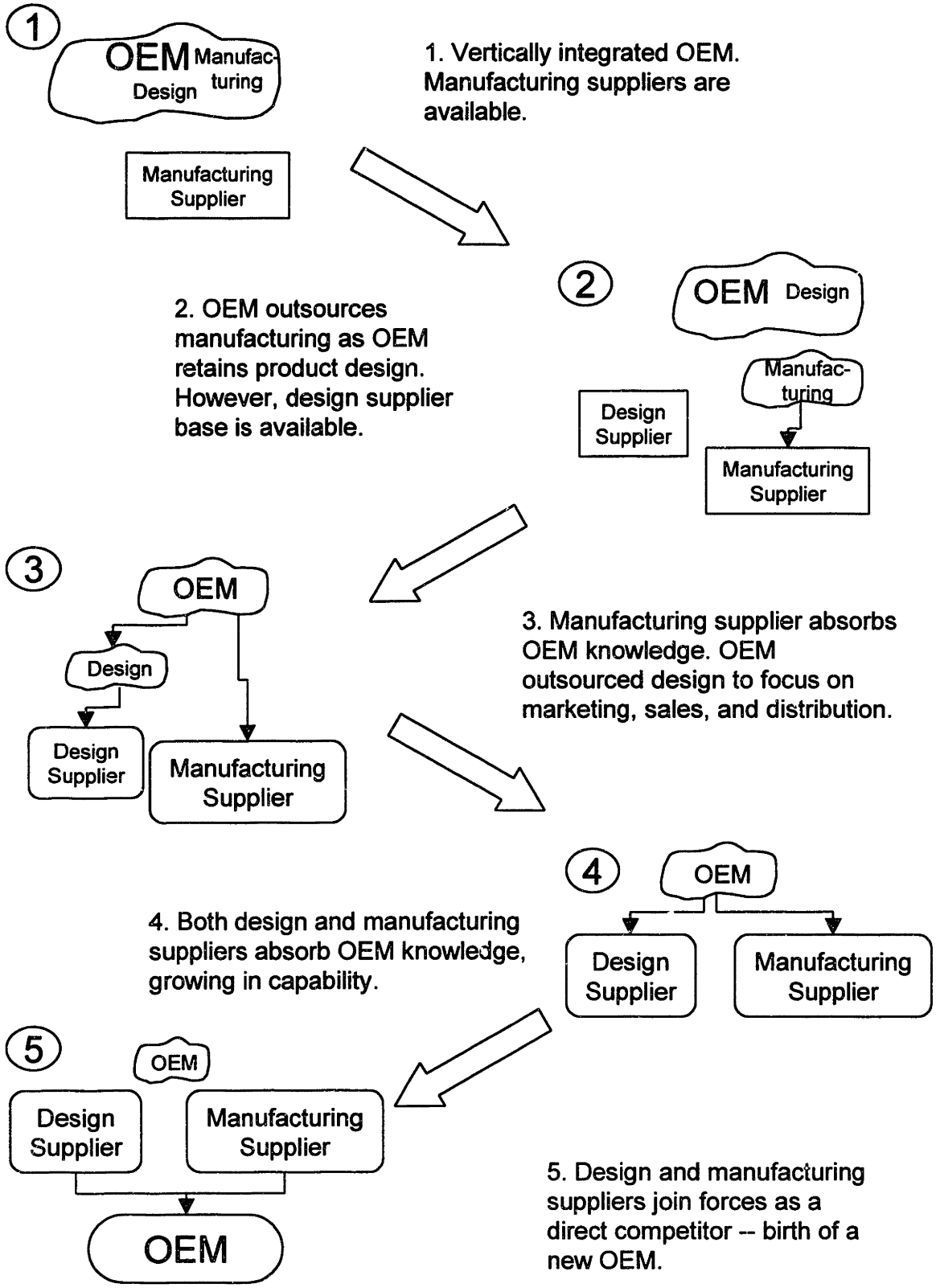

Figure 4-3: Natural Evolution of a New Original Equipment Manufacturer (OEM)

4.2.2 Supplier Holdup

In a scenario related to where the corporation is dependent on the supplier for design, there is always a risk of supplier holdup. In other words, if the supplier determines that it has greater bargaining power than the corporation, it could use its power to leverage additional concessions. If the supplier does use this tactic, there are ramifications for both the corporation and the supplier. The corporation has budget and schedule outcomes with which to contend. The design supplier might sacrifice its reputation as a supplier.

The computer industry provides some insight into exactly this swap in buyer-supplier power. Intel and Advanced Micro Devices (AMD) design and manufacture chips (microprocessors) for personal computers. The major computer manufacturers, such as Compaq, Dell, and Gateway negotiate with Intel and AMD to buy their chips. However, there are always more requests for the highest performing chips than either Intel or AMD can fill. Therefore, the suppliers ration the chips among all of their customers. Intel and AMD hold significant power in the negotiations to supply the chips. Those companies that are not successful getting the quantities of chips that they desire know that they will lose sales as a result.

When applying this analogy to other design outsourcing situations, the unique design and manufacturing skills of Intel and AMD for a unique product must be considered. However, whenever a design is outsourced, the corporation becomes dependent on that supplier for the unique knowledge that the supplier generates during the engagement. That knowledge, like the product, becomes another source of supplier power that can be a source of holdup.

4.2.3 Remaining a Knowledgeable Buyer

We have all experienced purchasing a product where there is knowledge asymmetry. The salesperson knows much more about the product that we do. Once we have experienced this situation, we tend to try to correct it for the next purchase by becoming more educated about the product. We want to be knowledgeable buyers to ensure we are making a good purchase decision and are not being cheated.

When design is outsourced, a corporation runs the risk of losing its ability to make a wise purchasing decision. Information asymmetry occurs between the corporation and the supplier of the design. The extent of this asymmetry is dependent on the amount of knowledge transferred

during the product development and the ability of the receiver (the corporation) to understand this knowledge through a common language.

According to 9th Wave, product design requires a lot of learning about how the product gets used. As a firm, they learn much more from doing the design work than from doing just the manufacturing. Corporations that are outsourcing their product's design and retaining managers to coordinate the design activity with their suppliers, must ask themselves whether they are assuming the risk of becoming unknowledgeable buyers of their product designs.[106]

4.2.4 Loss of Corporate Innovation

Product knowledge and design knowledge are symbiotic. If one has intimate knowledge about a product, it may still not be able to effectively design the product, because it does not know the "why" of the design. In turn, this leads to an inability to innovate and a dependency on external sources for that innovation. This is already happening in the Detroit auto industry where, according to Sperling, most innovation now occurs outside Ford, GM or Daimler-Chrysler. Their tiers of suppliers are not only tasked with manufacturing, but also the design of major components. For example, the leading designer of vehicular fuel cells is Ballard Power Systems in Vancouver, B.C. As automobiles shift towards new technologies, such as hybrid drive systems, it is likely that design outsourcing will accelerate.[107]

When a design supplier is servicing multiple clients in the same market for competing products, a corporation incurs the risk of reduced innovation. For example, sometimes Solectron's engineers find themselves designing products for competing clients.[108] Because the same designers in the supplier firm are exploiting essentially the same knowledge base, the innovation in these products will accordingly suffer. This situation is exasperated as the product firms become less familiar with the product and more dependent on the supplier.

---

[106] Ed Gilchrest, Interview at 9th Wave Inc. (Southbury, CT: March 4, 2000).

[107] Daniel Sperling, "Managing Innovation: Supercar Shows How Partnerships Can Falter," Inside R&D (April 9, 1997), p. 4.

[108] Scott Thurm, "Solectron Becomes a Force in 'Stealth Manufacturing'," Wall Street Journal (August 18, 1998), p. B4.

4.2.5 Does Long-Term Design Outsourcing Affect Industry Innovation?

In the long-term, the effects on innovation may be less desirable. As design suppliers merge and grow in strength and capabilities, more of the industry original equipment suppliers seek out the declining number of design suppliers. However, as the pool of suppliers shrinks and the design expertise within the buying companies fades, the companies' ability to perform the role of an informed buyer and innovation contributor fades also. In time, the design supplier is relying solely on its internal expertise and its supplier network for the design of its products. As diversity of input fades, the long-term ability for the supplier to innovate may be affected.

Leonard coined the term "signature skills" to describe the tendency for individuals – and I propose organizations also – to become highly skilled at applying preferred solutions to problems, sometimes even becoming emotionally attached to their bias.[109] Bleck Design commented that they have seen designers that always solve problems the way that they have in the past.[110] Elements of this characteristic can underlie the "not invented here" syndrome. As the preference builds and is repeated more often, the solution becomes a signature of the individual, or organization. Leonard attributes a signature skill to three interdependent preferences: preferred task, preferred cognitive approach (or style) and preferred technology. Figure 4-4: Composition of Signature Skills shows their relationship to signature skills.

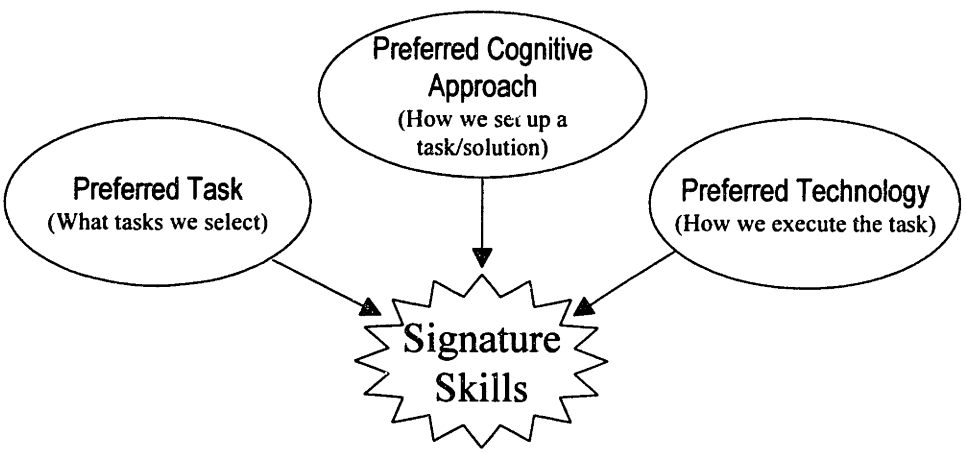

Figure 4-4: Composition of Signature Skills[111]

---

[109] Dorothy Leonard, Wellsprings of Knowledge: Building and Sustaining the Sources of Innovation (Boston, MA: Harvard Business School Press, 1998), pp. 62-63.
[110] Jim Bleck, Interview at Bleck Design Group (Chelmsford, MA: March 8, 2000).
[111] Dorothy Leonard, p. 63.

Applying these preferences in product design creates families of products that resemble one another. A signature skill transformed to a product does not imply the same characteristics as a dominant design as described by Utterback.[112] Rather, the product exhibits idiosyncrasies that are indicative of the individual or organization that designed it and distinguishes it from other products in the same design space.

When a signature skill is especially valued, it is pursued and reinforced until it is superseded and becomes obsolete. I contend that this characteristic witnessed in individuals is also evident in organizations with similar affect. However, when a high technology signature skill is resident in one or a few design suppliers, and the corporation no longer harbors the knowledge domain that could contribute to the design, innovation suffers. As Leonard states, "innovation occurs at the boundaries between mind-sets, not within the provincial territory of one knowledge and skill base." This is why Leonard recommends a "creative abrasion" between mind-sets to encourage innovation.[113]

4.3 Design Outsourcing Benefits

One of the positive findings of this thesis investigation was that the risks of design outsourcing are at least partly balanced by the benefits (ignoring the earlier mentioned market entry and risk-sharing benefits). It is just as important to expose these benefits and ensure that they are equally considered in a corporation's design outsourcing decision. The following paragraphs seek to describe those benefits including knowledge fertilization, designer motivation and product rejuvenation, and other benefits.

4.3.1 Knowledge Fertilization

Prior to conducting any of the product development firm interviews, my one-sided perspective prevented me from seeing one of the most significant benefits that can be accrued from outsourcing the design of one's products – the ability to learn from one's design supplier. Any company with an internal design organization runs the risk of incestuous thinking and diminishing innovation. Like a garden that is never fertilized, the first year's harvest may be

---

[112] James M. Utterback, Mastering the Dynamics of Innovation (Boston, MA: Harvard Business School Press, 1996).

[113] Dorothy Leonard, Wellsprings of Knowledge: Building and Sustaining the Sources of Innovation (Boston, MA: Harvard Business School Press, 1998), p. 64.

abundant, but production each year afterwards will be successively poorer. To keep innovation and production high, a design organization, like the garden, must be fertilized. New employees along with new design problems help provide the atmosphere for new knowledge generation and continued innovation.

Design outsourcing on a cyclic basis can help break old design habits. Leveraging the knowledge exchange that takes place during design with a design supplier, a company can learn new problem solving methods, new technologies, new product development skills, and new supplier networks while generating new sources for future innovation. The product development firms were able to describe their knowledge management skills specifically employed to gather knowledge during their engagements, disseminate it and then apply it to new projects. As one firm said, "You're going to school here just as much as you're working here."[114] There is a great tendency on the part of the corporation to overlook this source of knowledge that can be tapped for more than the brief period of their product development engagement.

4.3.2 Designer Motivation and Product Rejuvenation

Besides providing an auxiliary source for new knowledge and innovation, the right design outsourcing can help maintain a motivated internal design organization by letting it focus on more exciting and innovative projects. Products that are near the end of their lifecycle may especially need a fresh design approach to extend their life. Rather than giving this task to the same design group that has done the past few product design iterations, the iterative design can be outsourced. The internal design force is then retained for more advanced projects. This practice serves the corporation in three ways. The internal design force is more motivated to work on the new products, it learns how to rejuvenate its older products from the design supplier, and the knowledge that is transferred to the supplier may be less competitively sensitive.

4.3.3 Other Benefits

Many of the reasons for outsourcing described in paragraph 2.2.1 A Willingness to Outsource Design – Why Outsource Design? also imply benefits that are sought by the corporation when a design is outsourced. These benefits include reducing direct costs, making up for a shortage of resources or skills, speeding time-to-market of the product, skirting political

---

[114] Anthony Pannozzo, Interview at Herbst Lazar Bell (Waltham, MA: March 10, 2000).

barriers, permitting a greater focus on the core competence of the firm, and improving innovation through an exposure to new ideas. The question for the corporation and the subject of this thesis is whether these benefits can be sustained. There must be dependencies and modifiers that affect the severity of risk, the magnitude of the benefit and the sustentation of any advantage gained through design outsourcing. A corporation must consider these factors during the design outsourcing decision.

4.4 Dependencies and Modifiers

The strategic risks and benefits described in the previous paragraphs are each influenced by the unique nature of each outsourcing instance. Some of these influences are: the internal design capability, the knowledge intensity of the product and the existence of any knowledge kernels, whether the entire product is outsourced or just a module, the amount of integration necessary for the design, the clockspeed and attractiveness of the industry, and the method chosen for outsourcing the design.

4.4.1 Internal Design Capability – Still a Smart Buyer

When a design capability is retained internally, the corporation can retain a power balance in its dealing with the supplier from the reduced dependency on the supplier. The corporation becomes a smarter purchaser of designs, lowering the risk from supplier holdup. Also, when there is a common language as discussed in paragraph 3.3.2.1 Common Language, there is a greater likelihood of knowledge being transferred and sticking to the corporation.

Having an internal design capability also lowers the risk that a knowledge kernel will be outsourced. Because knowledge does get transferred during design, saving the kernels for internal design reduces the kernel-specific knowledge, though not eliminate it.

4.4.2 Knowledge Intensity and Knowledge Kernels

The design outsourcing of a knowledge intensive product represents a very different risk compared to one that is not, because of the knowledge that will be created and transferred. For example, in the auto industry, the outsourcing of the design of the coolant overflow bottle represents a different risk than outsourcing the design of the engine.

Likewise, outsourcing the design of a knowledge kernel or related components will expose the corporation to the risk that comes from transferring its unique knowledge to others.

The interviewed product development firms described how they build their knowledge from one product engagement to another. Once successfully transferred, knowledge gained from the design process will find its way into other products designed by the supplier.

4.4.3 Outsourcing the Entire Product or Components

As discussed in paragraph 3.3.1 Integration and Collaboration, the knowledge that is exchanged during a design engagement is highly dependent on the product architecture. Basically, the more modular a product, the easier it is to outsource just a portion of the design and establish discrete interfaces for that module. The less the module comprises of the total product and the more discrete the interface, then the smaller the knowledge transfer that will take place and the lower the risk that competitive knowledge will be outsourced. But this can be a misleading tactic if the outsourced module has integrative requirements that extend beyond the purely physical interfaces. Determining the integrative impact of outsourcing a module requires the knowledgeable perspective of the designer(s) who have experience doing that design. They can provide input as to whether the knowledge intensity of the module presents an outsourcing risk.

4.4.4 Design Integration

The relationship of knowledge transfer between modularity and knowledge transfer is affected by the degree of integration necessary for the design. As modularity increases (integration decreases), knowledge transferred will decrease (increase). Integration in this sense is not just related to the purely physical interfaces. For example, in the design of a computer, the battery life determines size and shape, which impacts internal packaging and the design of many other components. Determining the integrative impact of outsourcing a module requires the knowledgeable perspective of the designer(s) who have experienced doing that design. They can provide input as to whether the knowledge intensity of the module presents an outsourcing risk.

4.4.5 Industry Clockspeed

One of the authors who explicitly addresses knowledge as part of an outsourcing framework is Fine in his recent book Clockspeed.[115] Fine defines clockspeed as the rate of

---

[115] Charles H. Fine, Clockspeed: Winning Industry Control in the Age of Temporary Advantage (Reading, MA: Perseus Books, 1998).

evolution for an industry. Each industry evolves at a different rate depending on its product, process and organization clockspeeds. Although the clockspeeds shown in Figure 4-5: Measuring Clockspeed – Sample Industries are the results of polling management and technical people and not empirical measurement, the concept it extends is applicable to outsourcing decisions and their perceived impact. For example, in the aircraft industry, whether it is military or commercial, the development of each new product takes years. Fine shows these industries' product and technology clockspeeds to be some of the longest.

Industry	Product Tech Clockspeed	Process Tech Clockspeed	Organization Clockspeed
FAST-CLOCKSPEED INDUSTRIES			
Personal computers	< 6 months	2-4 years	2-4 years
Computer-aided software engineering	6 months	2-4 years	2-4 years
Athletic footwear	< one year	5-15 years	5-15 years
Semiconductors	1-2 years	2-3 years	3-10 years
MEDIUM-CLOCKSPEED INDUSTRIES			
Bicycles	4-6 years	10-15 years	20-25 years
Automobiles	4-6 years	4-6 years	10-15 years
Computer operating systems	5-10 years	5-10 years	5-10 years
Agriculture	3-8 years	5-10 years	8-10 years
Machine tools	6-10 years	6-10 years	10-15 years
Pharmaceuticals	7-15 years	10-20 years	5-10 years
SLOW-CLOCKSPEED INDUSTRIES			
Aircraft (commercial)	10-20 years	5-30 years	20-30 years
Steel	20-40 years	10-20 years	50-100 years
Aircraft (military)	20-30 years	5-30 years	2-3 years
Shipbuilding	25-35 years	5-30 years	10-30 years
Petrochemicals	10-20 years	20-40 years	20-40 years
Paper	10-20 years	20-40 years	20-40 years
Diamond mining	Centuries	25-50 years	50-100 years

Figure 4-5: Measuring Clockspeed – Sample Industries[116]

Fine uses clockspeed to modify an earlier framework that relates outsourcing decisions to knowledge dependency, capacity dependency and product architecture. Fine argues that if the clockspeed is slow and numerous suppliers are available, then outsourcing the design and manufacturing has few strategic risks. But, in a fast clockspeed industry with few suppliers,

[116] Excerpted from Table A.1 from Charles H. Fine, Clockspeed: Winning Industry Control in the Age of Temporary Advantage (Reading, MA: Perseus Books, 1998), p. 239.

outsourcing a module may impose a risk to the company of losing control of a key subsystem, perhaps a knowledge kernel.[117]

I see the affect of industry clockspeed from the perspective of knowledge transfer and knowledge loss. The risk or benefit from design outsourcing will not materialize or be applicable in a period of time that is modulated by the industry clockspeed. For example, if an aircraft manufacturer develops a new way to design and analyze advanced composite parts as part of a new aircraft development, application of that knowledge to another aircraft might take years because of the span of time between new projects and applying new technologies.

4.4.6 Industry Attractiveness

The relative attractiveness of the industry will influence the willingness of the supplier to become a new entrant in the industry (see Figure 5-17: Design Outsourcing and Knowledge Transfer System Dynamics). The more attractive the firm, the more likely that a design outsourcing supplier will seek to join the industry by leveraging what it learns through design engagements. Along with the relative profitability of the industry, the attractiveness of the industry can be examined through a Porter's five forces analysis. This strategic analysis of the industry examines the threat of new entrants, the bargaining power of buyers, the bargaining power of suppliers and the threat of substitute products and services. The analysis must also include the rivalry among existing firms, industry concentration, asset specificity, complementors to the product, and the regulatory environment.[118]

4.4.7 Outsourcing Methods, or Who's Your Partner?

Design outsourcing can be accomplished using a variety of arrangements. The method selected can affect the risks or benefits from the outsourcing activity. Knowledge will be transferred to the supplier no matter which outsourcing arrangement is chosen, but its extent will vary.

---

[117] Charles H. Fine, Clockspeed: Winning Industry Control in the Age of Temporary Advantage (Reading, MA: Perseus Books, 1998), p. 171.

[118] Sharon M. Oster, Modern Competitive Analysis, 3rd ed., (New York: Oxford University Press, 1999).

There must also be a consideration of compatibility between the partners, ensuring that the corporation's design needs will be met by the design supplier. Some of the compatibility factors to be considered, as recommended by Bruce and Morris, are the personal characteristics of each party, the cultural characteristics of each company, the product requirements and the type of resource being used.[119] The types of external design resources that are available are presented in the following paragraphs.

4.4.7.1 Industrial Design Company

These companies are the traditional design consultants with varying expertise in many different areas of design depending on the firm. Engineering and manufacturing skills have typically been de-emphasized compared to design style. Because of their small size and generally reduced scope of technical or engineering knowledge, these firms are much less of a direct competitive threat.

4.4.7.2 Product Development Company

These firms have evolved from industrial design firms to become much more than designers. With more complete product development expertise, these firms are able to offer a suite of services that may include strategic positioning, conceptualization, detail design, rapid prototyping, tooling design, limited manufacturing and contract manufacturing coordination. The design supplier firms I interviewed fall into this category with each offering varying levels of service.

Though small (generally less than 40 people), these firms have perhaps the richest diversity of knowledge because of the general diversity of the projects they develop. A design engagement with these firms offers tremendous benefits because of the diversity of their skills and knowledge. But, depending on what is outsourced and the willingness of the firm to forward integrate, the exchange of knowledge with these firms can carry the risk of creating a supplier dependency or a new competitor.

---

[119] Margaret Bruce and Barny Morris, "Managing external design professionals in the product development process," Technovation 14 (November 1994), pp. 585-599.

4.4.7.3 Job-shoppers/Contract Designers or Engineers

A company contracts these temporary workers either individually or through a contracting company. Length of employment may vary anywhere from several months to several years, depending on the project or multiplicity of projects. These workers have been a staple in the aerospace industry for decades, where well-recognized cycles of the industry make hiring large quantities of direct employees unattractive. Work may be completed either at the product company's facility or, in a fashion similar to a separate design firm, at the designer's location. The services offered by these firms are industry specific design and engineering skills, which explains the greater tendency for use of this outsourcing in very complex integrated systems like aircraft, ships, automobiles and software. In essence, these workers are expected to perform like direct hires, but without the additional cost of employee benefits.

Contract employees can bring with them a diversity of experiences from having worked at other firms in the business. However, because they generally work inside the product company's plant functioning like individuals rather than a separate company, they are usually quickly assimilated into the norms of the contracting company. These employees are able to gather the most information about the design of a product compared to other outsourcing arrangements because of their close daily contact with the direct hires working on the same project. When the project is over, they are released and will generally be working for another company in exactly the same industry. However, there is no risk from direct forward integration from these essentially temporary labor firms.

4.4.7.4 Contract Manufacturers

As outsourcing has grown, especially in the manufacturing sector, contract manufacturers have branched out into other services, including design. A statement repeated by several product development firms was they find it especially difficult to compete against manufacturing firms that are willing to do the design at no cost for a guaranteed manufacturing contract. Some product development firms are adding manufacturing capability to compete more effectively against the contract manufacturers.

The large contract manufacturers pose the greatest direct competitive threat because of the knowledge they reap from their design and manufacturing roles. Companies like Solectron

that are quickly expanding their service offerings to many different smaller companies, raise questions about their strategic intent and their ultimate influence on the industries they serve.

4.4.7.5 Competitors

Through partnering, alliances, and joint ventures, original equipment manufacturers can join forces to exchange the roles of primary and secondary contractors. These relationships can be simple or complex with the definition of supplier or partner blurring in some cases. In some industries, such as aerospace, the significant risk and cost involved in bringing a new product to fruition has driven companies to commonly partner for new aircraft. In these cases there is no risk of forward integration by the supplier because it is already a competitor. The greater risk is surrendering critical knowledge during design collaboration. The benefit from working with an "equal" is that the companies already know the knowledge domains embodied in the product, ensuring that a foundation for design collaboration (a common language) already exists.

4.5 Chapter Summary

The decision to outsource the design of a product is a strategic decision that can change the organization and the industry. Considering the core competencies of the corporation are an important part of determining what knowledge assets are crucial to the long-term competitive advantage of the corporation. The risks encompassed in design outsourcing are primarily wrapped around the transfer and potential depletion or loss of knowledge, especially a knowledge kernel. Through the transfer of knowledge about the product and the industry, the supplier can challenge the incumbent original equipment manufacturers as a new entrant or through greater supplier power. Long-term corporate or industry innovation may also suffer.

The benefits to be gained through design outsourcing, other than risk sharing and market entry, are based on the transfer of knowledge from the supplier and the creative abrasion that can occur between the corporation and the supplier. Other benefits such as resource management or time-to-market were described by the interviewed product development firms in Chapter 2 as reasons why firms outsource.

The risks and benefits are dependent on and modified by how and what the corporation outsources. Industry factors, such as the clockspeed or its attractiveness will also change the risk/benefit relationship.

Current frameworks for outsourcing do not consider all the strategic implications of knowledge transfer during design outsourcing. In effect, corporations are outsourcing their knowledge.

Chapter 5. System Dynamics Understanding

Figure 5-1: Thesis Structure Highlighting Chapter 5 Focus, shows how this chapter builds on the strategic implications of design outsourcing discussed in Chapter 4. The discussion so far has focused on design, outsourcing, product knowledge, and strategic implications with some discussion about the feedback relationships between each. In this chapter these feedback connections are looked at more carefully in an attempt to show how their interrelationships can reinforce the growth in design outsourcing with few balancing interactions. The corporation is cautioned to consider these tendencies and recognize that design outsourcing must be considered for its strategic merit, not because of reinforcement from product configuration or the supplier base.

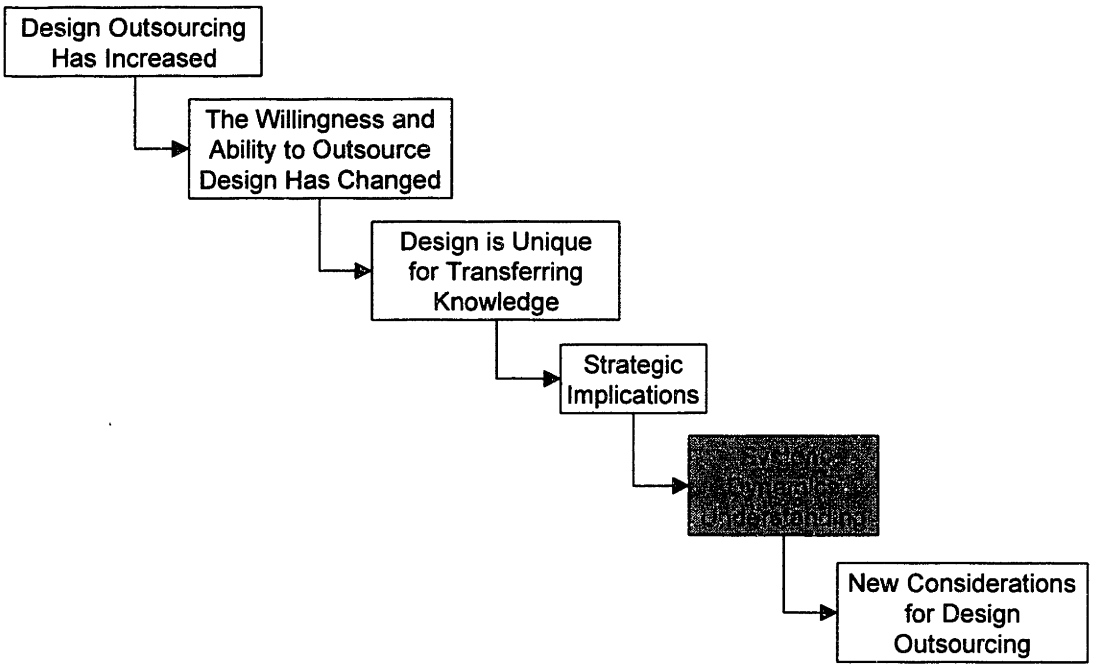

Figure 5-1: Thesis Structure Highlighting Chapter 5 Focus

This chapter will look at different pieces of the design outsourcing system, describing their importance and relating them to each other before constructing the entire system. This presentation should make the overall model more comprehensible.

5.1 Causal Diagrams

The following paragraphs present subset causal diagrams of the overall system dynamics system for design outsourcing and the resulting knowledge transfer.

5.1.1 Knowledge Stocks

The interviews with the product development firms validated the hypothesis that knowledge does flow from the client to the design firm and vice versa. The center of the strategic issue for the design outsourcing decision explored in this thesis is knowledge transfer between the original equipment manufacturer (OEM) and the design supplier (Supplier) as shown in Figure 5-2: Knowledge Stocks and Flows. In system dynamics, this transfer is represented as a flow – a flow of knowledge – from the OEM's stock of knowledge to the Supplier's stock of knowledge and vice versa. The stocks of knowledge are not directly connected, as in a pipe, because these are not rival or competing stocks. That is, the same knowledge can exist in multiple places at the same time.

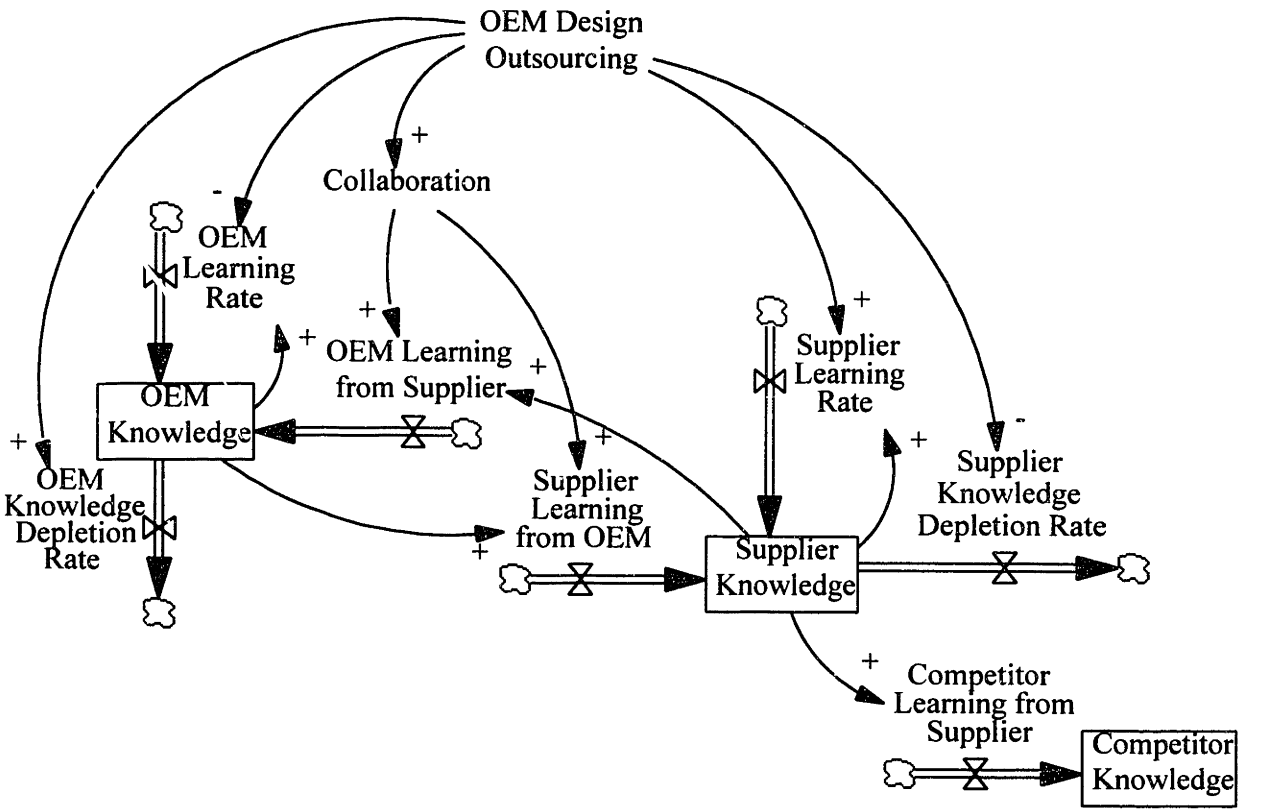

Figure 5-2: Knowledge Stocks and Flows with Driving Variables

The knowledge flows are conceptually controlled by valves that increase or decrease the flow of knowledge to and from the stocks. The variables that open or close the valves for knowledge transfer or learning are collaboration between the Supplier and the OEM, the amount of OEM design outsourcing, and the amount of knowledge that each stock has. As the amount of

collaboration increases, the flow of knowledge between the OEM and the Supplier increases.[120] In general, the greater the amount of design outsourcing done by the OEM, the less learning done by the OEM and the more learning done by the Supplier. In a related fashion, the OEM will unlearn faster and the Supplier will unlearn more slowly. This learning is a result of exogenous knowledge sources that are an integral part of the design process. The product development firms emphasized how they learn not only from their clients (both past and present) but also learned from many other sources, including the Internet, publications, and product consumers. The OEM's knowledge depletion increases because it is not using its resident knowledge. As either the OEM or the Supplier learns more, it creates a larger knowledge foundation for which to learn more as well as becoming a larger resource from which the other can learn.

One of the side effects of the Supplier gaining more knowledge is an increase in the knowledge transfer to the OEM's Competitors that will take place. As the Supplier learns more, it is able to apply that increased knowledge to other projects, including the OEM's Competitors'.

5.1.2 Collaboration and Knowledge Intensity

As the degree of technology integration (including systems integration), the number of product technologies and the amount of product testing and support increases, the design supplier will be less likely to have all the knowledge resident to execute the design without collaboration with the OEM. In other words, the greater the knowledge intensity of the product, the greater the collaboration that is required between the OEM and the Supplier to execute the design (see Figure 5-3: Collaboration and Knowledge Intensity Influences).

---

[120] Using conventional system dynamics conventions, a plus sign (+) denotes the variables connected with the arrow move in the same direction. As one increases (decreases) the other will increase (decrease) as a result. A minus sign (-) denotes an opposite movement. As the first variable increases, the linked variable will decrease as a result and vice versa.

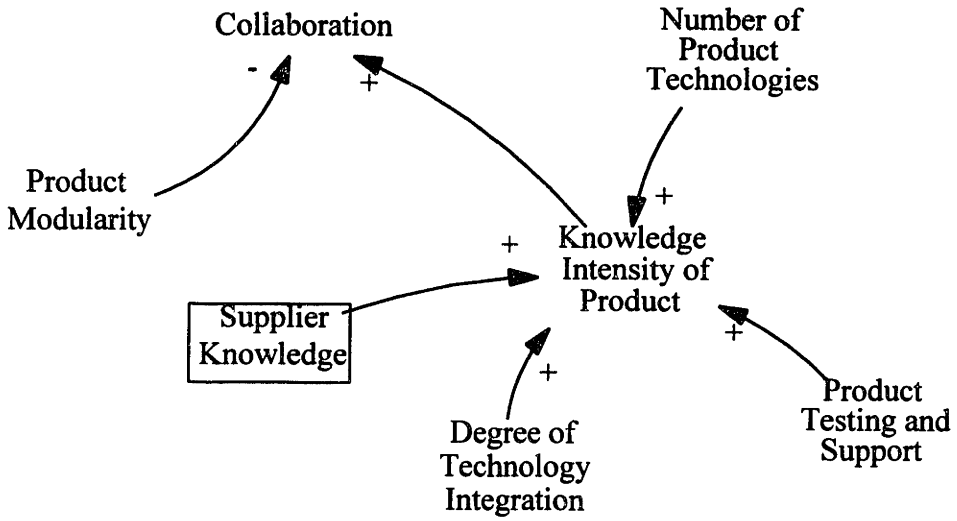

Figure 5-3: Collaboration and Knowledge Intensity Influences

A subtle contribution to the knowledge intensity of the product is a causal link from the Supplier stock of knowledge. As the Supplier's stock of knowledge increases, more of that knowledge can be used in the design and embodied by the product.

In paragraph 5.2.1.2 The Mass Customization Loops, the feedback loops associated with product modularity are shown to reinforce design outsourcing. Product modularity also has an opposite effect on collaboration between the OEM and the Supplier. The more that a product is modularized, the less that there is a need for the Supplier to be involved in product-wide collaboration to complete the design of their product module. Therefore, more modularity can actually reduce collaboration, limiting knowledge flow.

5.1.3 The Willingness of the OEM to Outsource the Design

Chapter 2 discussed the influences on a corporation's willingness to outsource the design of a product. Increasing this willingness is derived from internal and external pressures, the extent of product modularity, improvements in the design collaboration processes, and the developed trust between the OEM and the Supplier developed from previous design outsourcing. As Supplier knowledge increases, there is also an increased willingness to outsource the design because the OEM recognizes an ability to learn from the Supplier and/or the Supplier will not require as much management interaction to be able to execute on the design. These relationships are shown below in Figure 5-4: Drivers on the OEM Willingness to Outsource Design.

This figure also shows that there is a negative influence on the willingness to outsource design that comes from the OEM's sense that the Supplier will soon become its direct competitor. However, this appears to be a rather weak detractor from the willingness to outsource based on the product development firms interviews and the trends occurring at companies like Solectron. It may also be difficult for an OEM to judge a Supplier's strategic intent unless there is overt signaling by the Supplier.

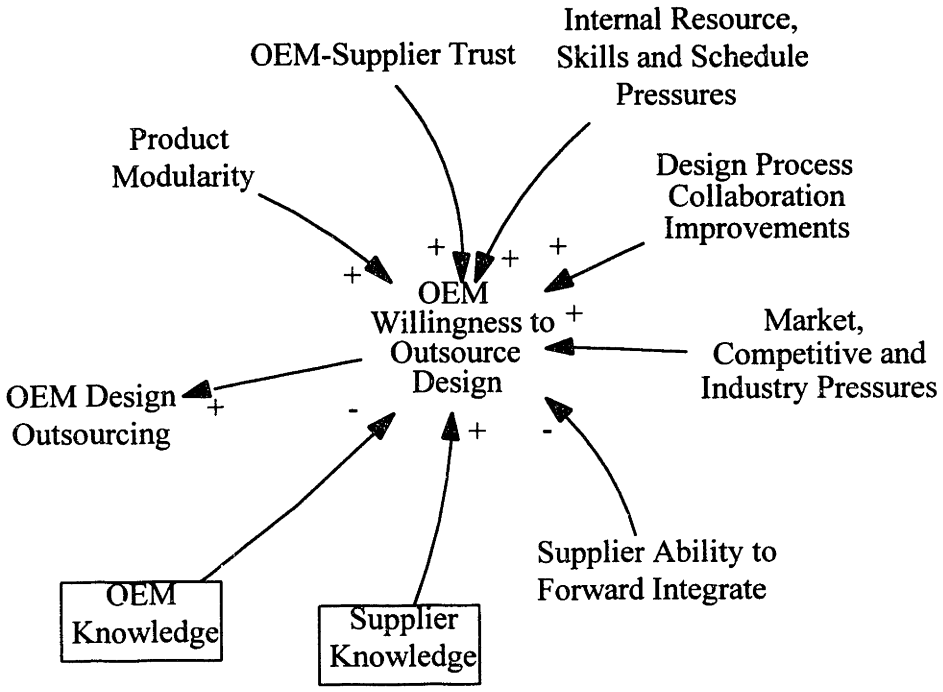

Figure 5-4: Drivers on the OEM Willingness to Outsource Design

5.1.4 OEM Design Outsourcing Variable Influences

Outsourcing the design is a function of the willingness and the ability to outsource as discussed in Chapter 2. As these factors increase, the design outsourcing increases as well. These relationships are shown graphically in Figure 5-5: Additional Drivers to and from OEM Design Outsourcing.

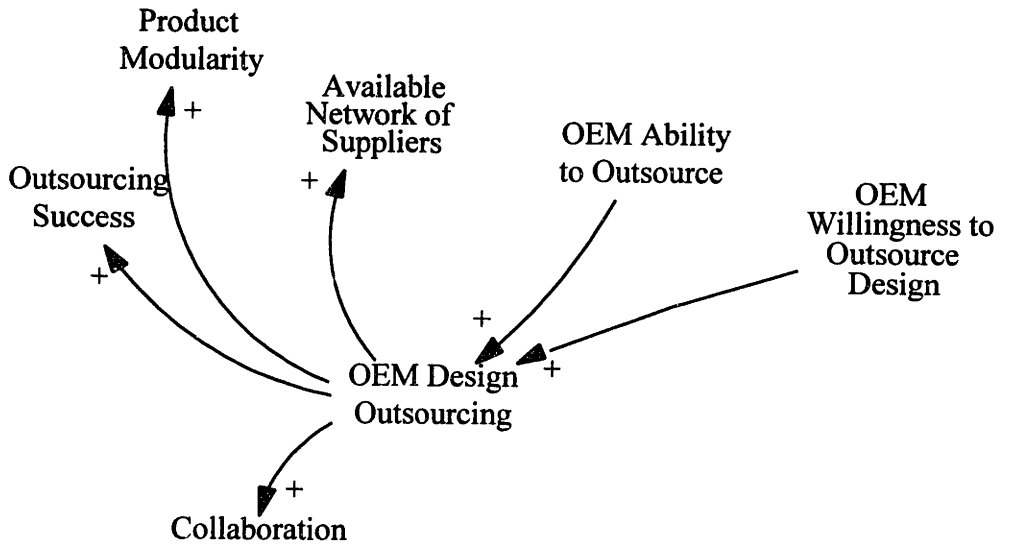

Figure 5-5: Additional Drivers to and from OEM Design Outsourcing

In turn, the amount of design outsourcing influences the learning and unlearning rates for the stocks of knowledge. These effects were previously shown in Figure 5-2: Knowledge Stocks and Flows with Driving Variables. Three other variables that are positively influenced by a greater amount of outsourcing, are modularity in the design, the perceived success in design outsourcing, and the availability of design Suppliers. This last causal relationship is a natural evolution of an industry. When the OEM makes more contracting opportunities available, more Suppliers will join the industry because of the business opportunity. Additionally, when more outsourcing is attempted by the OEM, the capacity to do the work may be too great for its current Supplier base forcing the OEM to qualify additional Suppliers to take on the OEM's work.

5.1.5 Forward Integration by the Supplier

The risk that initiated my investigation into the dynamics of outsourcing product design is the risk of forward integration by the supplier. I was intrigued by the idea that not only could a corporation lose its knowledge about design and the product, but that it could then be imposed upon by a more powerful design supplier that could leverage its knowledge to compete against the corporation. The variables that drive this phenomenon are an ability and willingness to forward integrate. The willingness to forward integrate is modified by the attractiveness of the OEM's market and the non-compete culture of the company. This last variable can be answered from asking, "what is the company's attitude towards competing with its clients?" Each of the product development firms, for example, were able to articulate their policies about competing

with their clients, or doing work for one client that was directly competitive with another client. The stronger this culture, the less likely that the willingness to compete will be strong enough to make Supplier forward integration feasible. This is shown in Figure 5-6: Causal Variables for Supplier Ability and Willingness to Forward Integrate.

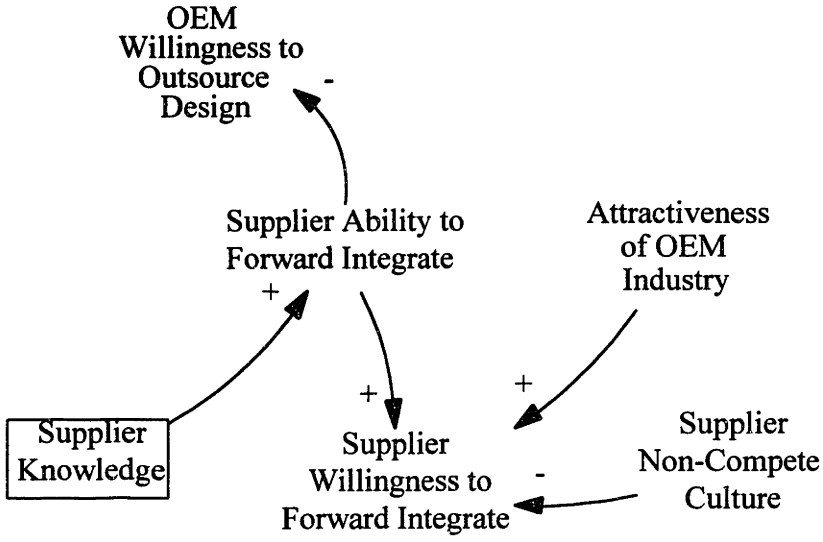

Figure 5-6: Causal Variables for Supplier Ability and Willingness to Forward Integrate

As the Supplier's knowledge grows, there is an increasing ability for the Supplier to forward integrate because the Supplier is learning through the OEM and its other sources about the product, production, the consumers and the industry, in general. This increased ability affects the Supplier and the OEM. It will increase the willingness of the Supplier to forward integrate while the increased sense of risk felt by the OEM will decrease the willingness of the OEM to outsource. However, as described earlier, this last causal relationship may be weak depending on the ability of the OEM to sense the Supplier's strategic intent.

5.2 The Feedback Loops

The aforementioned causal diagrams are combined below in their respective positive and negative feedback loops. Each loop reinforces or balances, respectively, the behavior of the total system. Delays are not shown, but can be imagined existing in almost every loop because of factors such as managerial inertia, industry clockspeed, resource hiring and attrition.

5.2.1 The Reinforcing (Positive) Feedback Loops

5.2.1.1 More Designers Loop

As design outsourcing increases, there is an increase in the available network of design suppliers. This growth adds to the ability to outsource the design, creating a positive, reinforcing loop called the "More Designers Loop" shown in Figure 5-7: The More Designers Reinforcing Loop. In essence, the design suppliers and the outsourcing of design create a complementary effect that leads to a growth in design outsourcing.

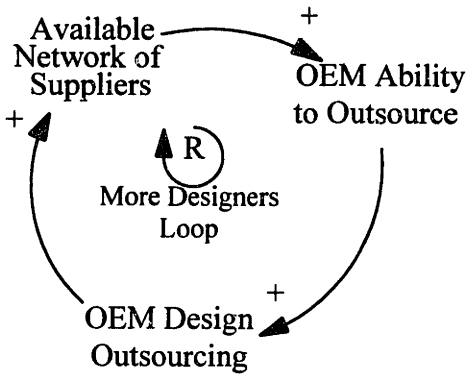

Figure 5-7: The More Designers Reinforcing Loop

5.2.1.2 The Mass Customization Loops

Also described Chapter 2 is the reinforcing affect of product architecture on the willingness and ability to outsource the design of a product. When a product is more modular in design, it is simpler to outsource the design of the product or product component. As outsourcing increases, the product architecture will increasingly become more modular to accommodate the outsourcing. This effect is shown in Figure 5-8: The Mass Customization Reinforcing Loops. The reference to mass customization in naming these loops is derived from the need for a mass customized product to have a modular architecture.

Another effect of modularity was discussed in paragraph 5.1.2 Collaboration and Knowledge Intensity. As modularity increases, a direct result can be a reduction in collaboration. That is, modularity can have a countering effect on the knowledge transferred from outsourcing by reducing the extent of knowledge that must be conveyed between the OEM and the Supplier to complete the product module design.

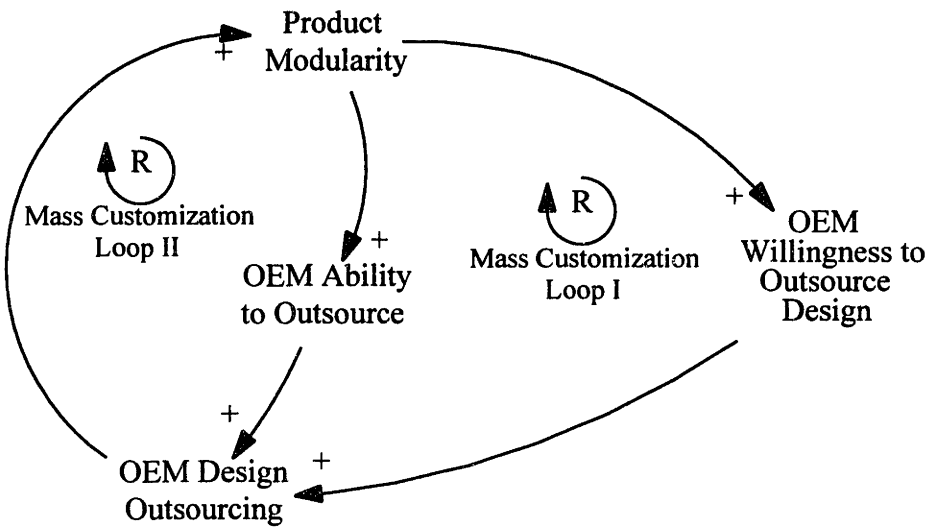

Figure 5-8: The Mass Customization Reinforcing Loops

5.2.1.3 The Smarter Supplier Loop

With an increased willingness to outsource design and a resulting increase in design outsourcing (all else being equal) there is an increase in the knowledge that is transferred to the Supplier from the collaboration that takes place between the Supplier and the OEM. As the Supplier's knowledge increases, an OEM is more willing to outsource the design to that Supplier because it has already learned about the OEM and its method of working. The OEM realizes that because the Supplier already has a relationship with the OEM, it can spend less time with the Supplier on the fundamentals. This effect is shown in Figure 5-9: The Smarter Supplier Reinforcing Loop.

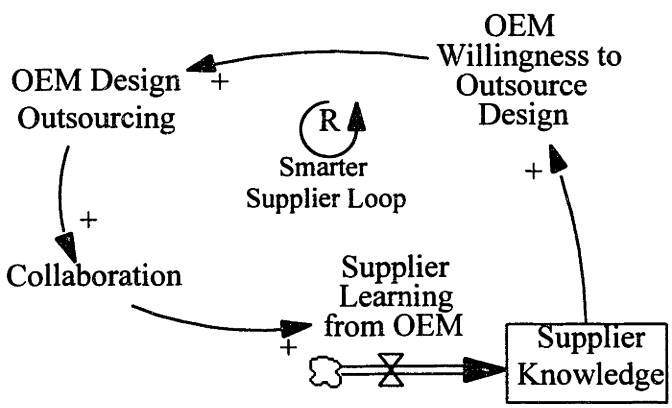

Figure 5-9: The Smarter Supplier Reinforcing Loop

5.2.1.4 The OEM Knowledge Depletion Loop

The reinforcing loop shown in Figure 5-10: The OEM Knowledge Depletion Reinforcing Loop, highlights the effect on the OEM from design outsourcing. The willingness to outsource and increasing outsourcing leads to not using knowledge in the OEM's knowledge stock and the knowledge becomes old or is forgotten. As the knowledge stock decreases, the willingness to outsource the design will increase because of the difficulties in doing the design internally. The feedback loop reinforces the tendency to outsource design. Linking the valve function to design outsourcing instead of the size of the OEM's knowledge stock emphasizes the fleeting qualities of design knowledge, especially with regard to technology products and the tacit element of design. If knowledge is not refreshed or used, it will be lost.

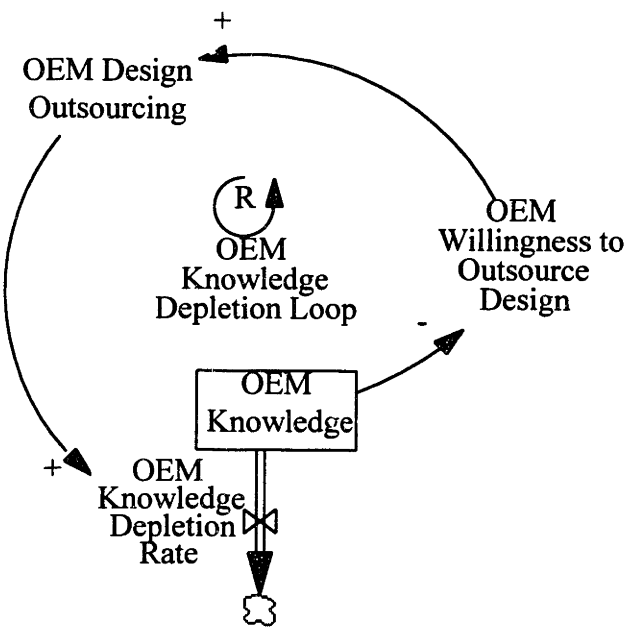

Figure 5-10: The OEM Knowledge Depletion Reinforcing Loop

5.2.1.5 The Supplier Slower Depletion Loop

In a corollary to the OEM Knowledge Depletion Loop, is the existence of the Supplier Slower Depletion Loop. This is shown in Figure 5-11: Supplier Slower Depletion Reinforcing Loop.

This loop shows the related effect on the Supplier from increased design outsourcing by the OEM. Increased outsourcing enables the Supplier to use the knowledge it has and fertilize it

with new knowledge gained from other sources. The knowledge depletion from the Supplier is thereby decreased leading to sustaining a knowledgeable Supplier and a greater willingness to outsource by the OEM.

As was done with the OEM knowledge depletion loop, linking the valve function to design outsourcing instead of the size of the Supplier's knowledge stock emphasizes the fleeting qualities of design knowledge.

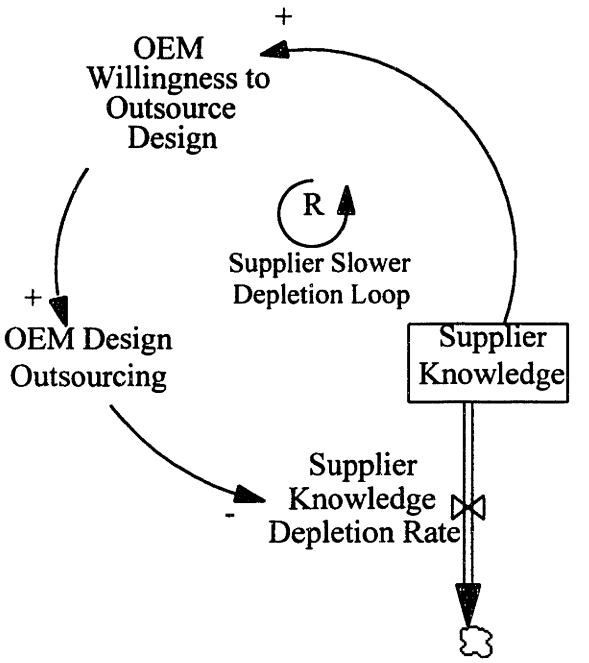

Figure 5-11: Supplier Slower Depletion Reinforcing Loop

5.2.1.6 The Success Loop

Increased design outsourcing will ingrain the outsourcing practices and trust that breed success. As trust builds, the willingness to outsource the design also builds, reinforcing the cycle of design outsourcing (see Figure 5-12: The Success Reinforcing Loop). The product development firms spoke of this relationship building. For example, Herbst Lazar Bell described the collaboration atmosphere with the client as "intense" and is characterized by friendships and "living with one another."[121]

[121] Anthony Pannozzo, Interview at Herbst Lazar Bell (Waltham, MA: March 10, 2000).

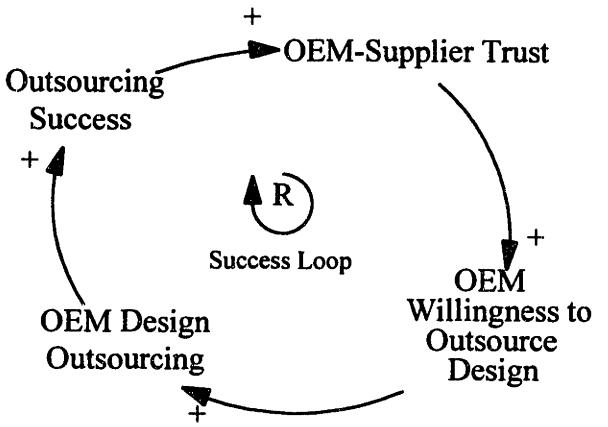

Figure 5-12: The Success Reinforcing Loop

5.2.1.7 The Intensity Loop

As the knowledge of the Supplier increases, the Supplier is able to work on more complex, more knowledge intensive product designs. The greater the knowledge intensity of the product, the greater the collaboration with the OEM that is required to successfully complete the design. This greater collaboration increases the knowledge flow to the Supplier.

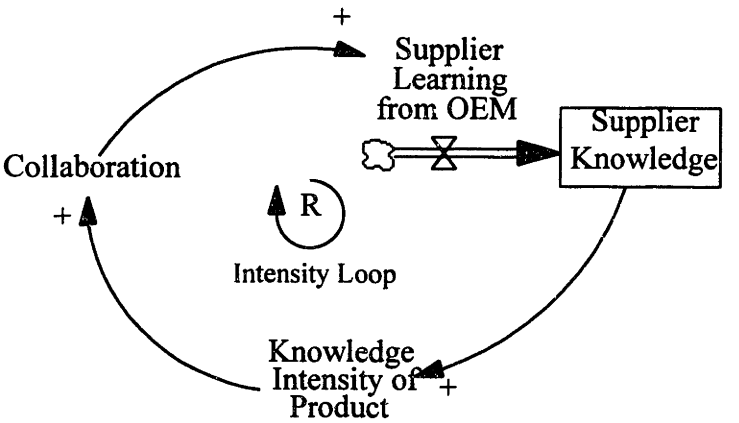

Figure 5-13: The Intensity Reinforcing Loop

5.2.2 The Balancing (Negative) Feedback Loops

5.2.2.1 The Concerned OEM Loop

Figure 5-14: The Concerned OEM Balancing Loop shows the causal-loop diagram for when the OEM realizes the Supplier has gained significant knowledge and power to be able to challenge it directly in its market. In general, with everything else being equal, as the Supplier's ability to forward integrate increases, the OEM's willingness to outsource decreases.

There are also other possible actions that may result including forming a contractual alliance or partnership with the supplier, forming a merger, or acquiring the Supplier. In the case of a merger or acquisition, the dynamic result is the same. The design is moved internally and design outsourcing is reduced.

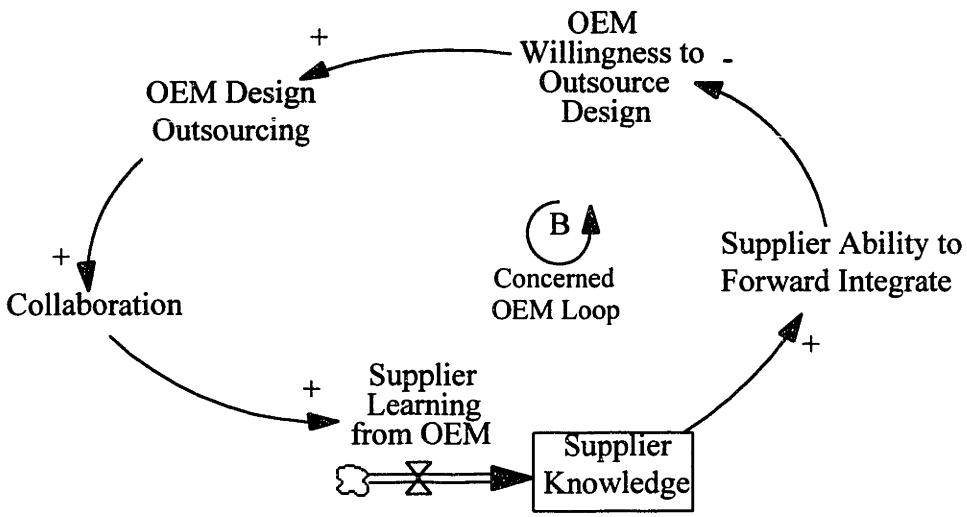

Figure 5-14: The Concerned OEM Balancing Loop

5.2.2.2 The Smart Supplier Loop

One of the perceived advantages of outsourcing the design to a knowledgeable Supplier is the reduction in overhead and time needed to bring the supplier up to speed on the project. The Supplier may already have an extensive background in the industry and has the common language to quickly proceed productively. A Supplier who does not have these attributes will require more interaction with the OEM. The effect of the knowledgeable supplier sets up a balancing loop that is shown in Figure 5-15: The Smart Supplier Balancing Loop.

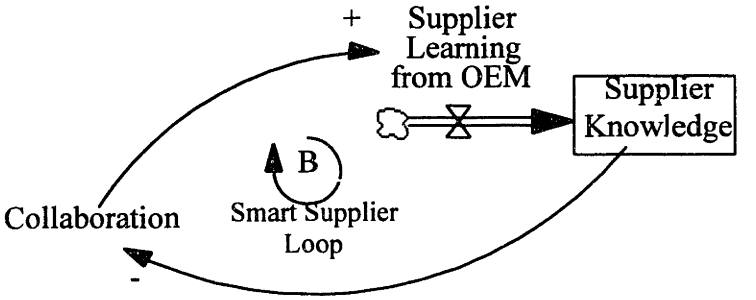

Figure 5-15: The Smart Supplier Balancing Loop

5.2.2.3 The Outsourcing Needs Loop

The same increase in collaboration that reinforces knowledge transfer to the Supplier, is balanced by the flow of knowledge away from the Supplier. Collaboration is good for the OEM and the Supplier. However, the rates of knowledge transfer are different, leading to a separately defined feedback loop. See Figure 5-16: The Outsourcing Needs Loop. In this case, the increased knowledge of the OEM leads to a reduced willingness to outsource – the OEM knows how to do it and keeps the work internally. Product Genesis saw evidence of this balancing loop in new designs of their client's products that were not done by Product Genesis, yet the products embodied characteristics learned from their design engagement with Product Genesis.[122]

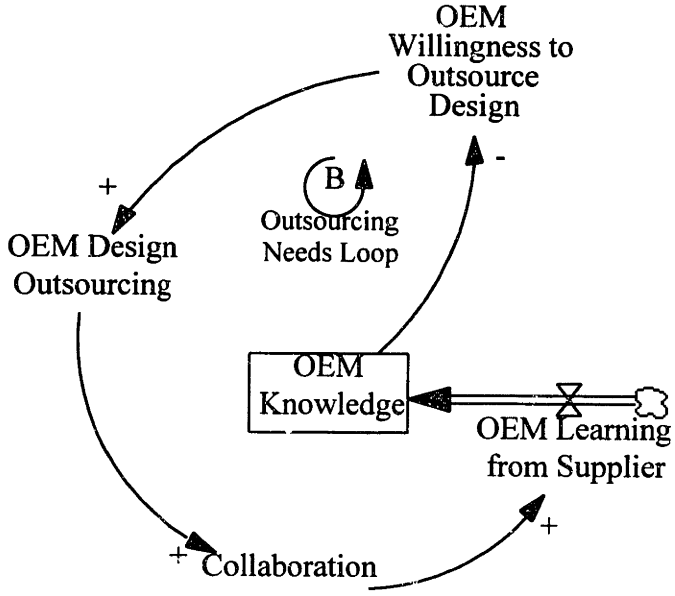

Figure 5-16: The Outsourcing Needs Loop

5.3 The Complete System Dynamics Model

The assembled model is shown in Figure 5-17: Design Outsourcing and Knowledge Transfer System Dynamics. To simplify the complete representation of the model and enable focusing on the important feedback loops that drive the system, the learning from other sources for the knowledge stocks and the contributing effects of knowledge intensity have been hidden. Also, product modularity has been repeated for the causal link to collaboration.

[122] Brian Vogel, Interview at Product Genesis (Cambridge, MA: March 6, 2000).

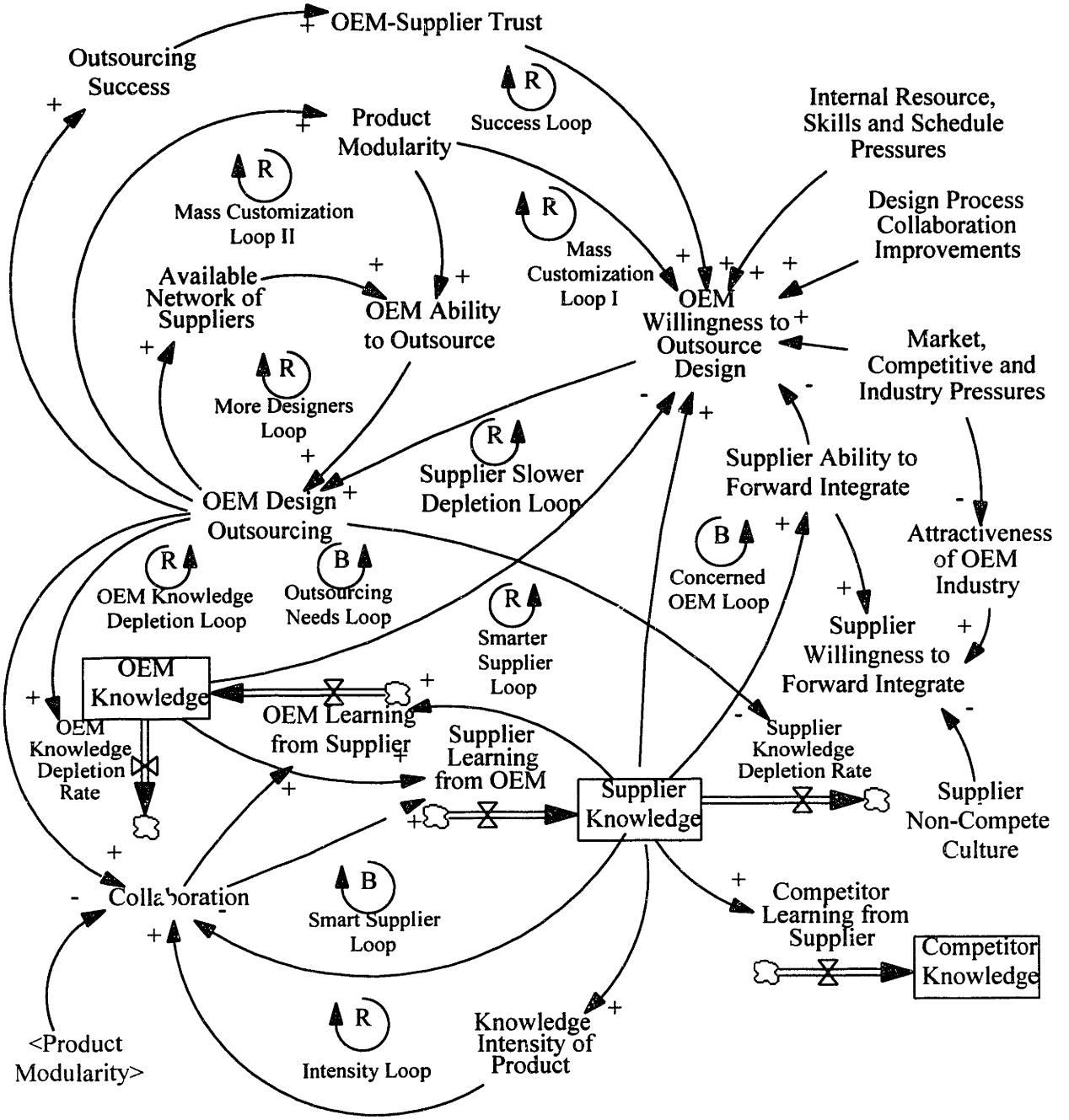

Figure 5-17: Design Outsourcing and Knowledge Transfer System Dynamics

The immediately noticeable feature of this system is the eight to three ratio of reinforcing loops to balancing loops. For an OEM thinking about outsourcing its product designs, it must realize the tendency for the reinforcing behavior of this practice and increasing knowledge loss, leading to an increased dependency on the design Supplier. As this dependency grows and the

Supplier becomes more capable of competing directly with the corporation, other factors that essentially influence the Supplier's strategic intent will determine whether that step will be taken.

There are delays in many of the feedback loops represented in this model. For example, one can easily imagine a delay between an increase in an OEM's design outsourcing and a resulting increase in the availability of design suppliers. Likewise, there is a delay between a Supplier's ability to forward integrate and the OEM's recognition of that ability, leading to a decrease in its design outsourcing. The OEM may have multiple design projects already outsourced at various stages of completion, making it impossible to instantaneously reduce outsourcing. Using Fine's terminology[123], as the clockspeed of the industry lengthens, the delays in the system would decrease. The delays create another result for this system – oscillations that complicate the ability to predict the exact interaction of the feedback loops.

Although mathematically modeling this system has not been undertaken as part of this thesis, predicting the outcome may be made from what has been learned. This prediction is shown graphically in Figure 5-18: Predicted Amount of Design Outsourcing versus Time. Its derivation is based on knowing that there is an obvious upper bound to the amount of design outsourcing that can be done by the OEM. Once all of the OEM's products have been outsourced for their design, no more design outsourcing can be done. Because of the much greater number of reinforcing loops compared to balancing loops, the tendency to outsource design is predicted to grow as more design is outsourced. Eventually, the OEM begins to lose its design capability and the Success Loop comes into play, rapidly leading to all of the design being outsourced.

However, as the design suppliers grow stronger and the OEM is the target of increased direct competition from its Suppliers, it may try to pull design back in-house, if it is able to rebuild a design capability through hiring the right skills (perhaps from its suppliers). The predicament it will face is whether it can hold on long enough to avoid an incursion by its Suppliers and Competitors.

---

[123] Charles H. Fine, Clockspeed: Winning Industry Control in the Age of Temporary Advantage, (Reading, Mass: Perseus Books, 1998).

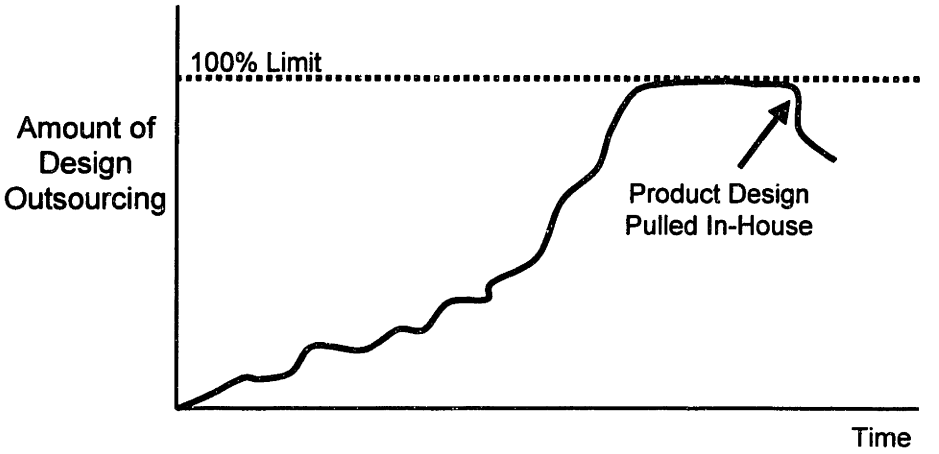

Figure 5-18: Predicted Amount of Design Outsourcing versus Time

This prediction is not a fait accompli for the OEM. There are companies that have used design outsourcing of their products and have been very successful. With the greater number of positive feedback loops in the system helping to reinforce design outsourcing, the companies that remain successful with this practice have achieved an ability to balance the dynamics of knowledge transfer and product design. Chapter 6 provides recommendations to limit the risks associated with design outsourcing.

5.4 Chapter Summary

The self-perpetuating features of design outsourcing are revealed through the creation of a system dynamics model that builds on what has been learned about design, knowledge transfer and the strategic implications of this practice. With a ratio of eight reinforcing feedback loops and three balancing feedback loops, the model implies that design outsourcing and knowledge transfer are easier to start than to stop. Although the model is not programmed and executed, an attempt at predicting the model's response emphasizes the effects of system delays, exponential growth and eventual reversal of some design outsourcing. In Chapter 6, new considerations for design outsourcing are presented that will help minimize the risks and maximize the benefits from design outsourcing.

Chapter 6. New Considerations for Design Outsourcing

Consideration of the strategic risks and benefits and the potential outcome of design outsourcing may still lead to a decision that the design outsourcing is the best decision. Once that decision is made, what other factors should be considered? This question is explored in this chapter. As shown in Figure 6-1: Thesis Structure Highlighting Chapter 6 Focus, this chapter provides new considerations for design outsourcing.

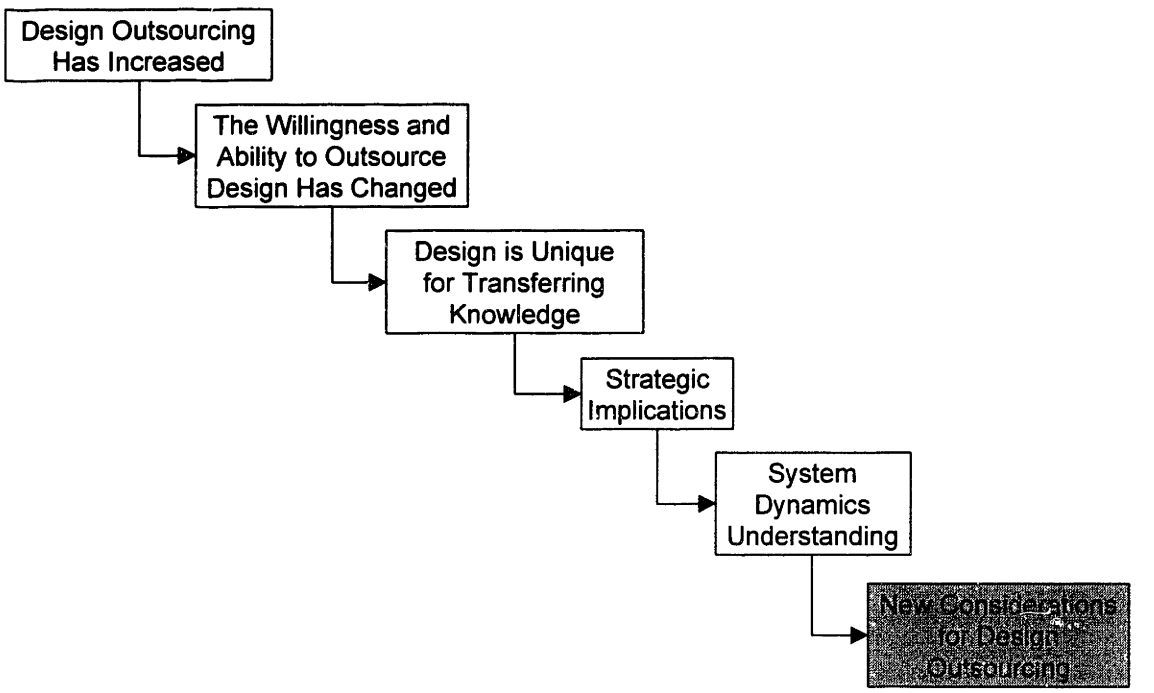

Figure 6-1: Thesis Structure Highlighting Chapter 6 Focus

The design outsourcing system dynamics modeling in Chapter 5 highlights the causal relationships that foment knowledge transfer and could lead to forward integration of the design supplier. However, to recommend that long-term competitive advantage can only be sustained by not outsourcing the design of any products is ignoring the benefits in innovation and knowledge transfer to the corporation that can be gained from this practice.

This chapter provides recommendations for the management of any corporation currently or contemplating outsourcing the design of its products. The first step is to establish a knowledge foundation for outsourcing. Recommendations are then given from an offensive perspective – using design outsourcing to gain competitive advantage – and then a defensive perspective – protecting important knowledge during design outsourcing. These recommendations are derived

from the system dynamics analysis, the interviews with the product development firms and the earlier chapters on design and knowledge transfer.

6.1 Establish a Knowledge Foundation for Outsourcing

Outsourcing is ultimately a strategic decision. Design outsourcing is strategically unique because it outsources the knowledge of the company. Therefore, an understanding of the company's knowledge foundation must be established before outsourcing the design of a product. This foundation is built by understanding the knowledge intensity of the products and by defining the product knowledge kernels. A knowledge audit can then help determine if current design practices should be modified.

6.1.1 Understand the Knowledge Intensity of Your Products

By understanding the relative knowledge intensity of your products, you are able to determine those products that embody the most knowledge of the organization and therefore the most investment. Protecting that investment and leveraging it for competitive advantage is one consideration during an outsourcing design decision.

For example, in the case of the helicopter manufacturer that outsourced its airframe design, a large landing gear support structure fabricated from a new material would have more knowledge intensity than an electrical harness support bracket. As an example of how knowledge intensity can be understood at the system level, the resources needed to design and integrate the airframe with the other major aircraft systems contribute to making the airframe subsystem much more knowledge intensive than, say, the environmental control subsystem.

6.1.2 Define Your Knowledge Kernels

A knowledge kernel is the product or product component which provides the company with competitive advantage. It is the embodiment of the core competencies in the firm and is therefore unique and difficult to imitate. Asset specificity may help in narrowing the list to define a knowledge kernel, but not always. Significant investments in particular test equipment or customized machinery can provide clues, especially when these investments are disproportionate to your competitors in the same industry. Using the helicopter manufacturer example again, although significant asset specificity and other internal resources are dedicated to the design, manufacture and testing of the airframe, other aerospace manufacturers have similar equipment,

providing similar capabilities. However, in some areas, such as composite airframe design, it may have a unique capability that is derived from design software and manufacturing development.

In defining their similar concept of a core product, Hamel and Prahalad recommend thinking in terms of a manufacturing share, not in terms of market share. For example, Matsushita had in 1990 an estimated world manufacturing share of compressors even though its air conditioning and refrigerator business brand was small.[124] However, it may be an element of the compressor, perhaps the control electronics, or the turbine design that is truly the knowledge kernel for this product. Knowing which elements are the knowledge kernels will properly focus corporate energies on building and retaining this knowledge, while ensuring they are considered during any outsourcing decision.

6.1.3 Perform a Knowledge Audit

Once you understand the knowledge intensity of your products and what product(s) comprise the knowledge kernel(s), you must determine whether your current design practices support maintaining the knowledge base for your products. A knowledge audit can help with this task by reviewing how the knowledge in your products is created, codified, disseminated and reused. The audit information will help determine if your design group and your products might benefit or be hurt by design outsourcing. For example, if you have a small design organization that is crucial to your knowledge kernel, does it make sense to outsource the next new design of that product? In a similar vein, if this same design group has had no personnel turnover in five years, an exposure to design outsourcing might inject new creativity.

6.2 Offense: Use Design Outsourcing to Gain Competitive Power

There are benefits to design outsourcing which are apparent in the successful products designed by IDEO, Ziba Design, Altitude, Herbst Lazar Bell and others. Outsourcing the design to a product development firm, a contract manufacturer, or contract employees will transfer knowledge. The key is then how to extract the most benefit from this relationship, using design outsourcing offensively.

---

[124] C. K. Prahalad and Gary Hamel, "The Core Competence of the Corporation," Harvard Business Review 68 (May-June 1990), p. 85.

6.2.1 Use Design Outsourcing to Learn

Extracting the most benefit from design outsourcing requires recognizing that products are developed from knowledge. Creativity and innovation will flow from a diversity of knowledge. The same strategic emphasis that the product development firms place on learning from each design engagement and building on that knowledge in the next engagement should be adopted by the design outsourcing corporation. Design suppliers can help provide ideas for implementing knowledge management practices. This must extend beyond the archiving of data, drawings and CAD models from design projects because design knowledge is not just explicit knowledge.

Outsourcing design can also provide a benchmarking opportunity. Design practices and technologies learned elsewhere may provide a key insight into corporate design deficiencies that would not be apparent if a total internal focus were maintained.

There are two suggested patterns of design outsourcing that can help refresh an internal design force. One is exploratory design outsourcing and the other is incremental product design outsourcing.

6.2.1.1 Exploratory Design Outsourcing

One method to "fertilize the knowledge garden" is to periodically outsource the design of a new product to force the collaboration that will transfer knowledge about other firms' design practices. Graphically, this is shown in Figure 6-2: Exploratory Design Outsourcing.

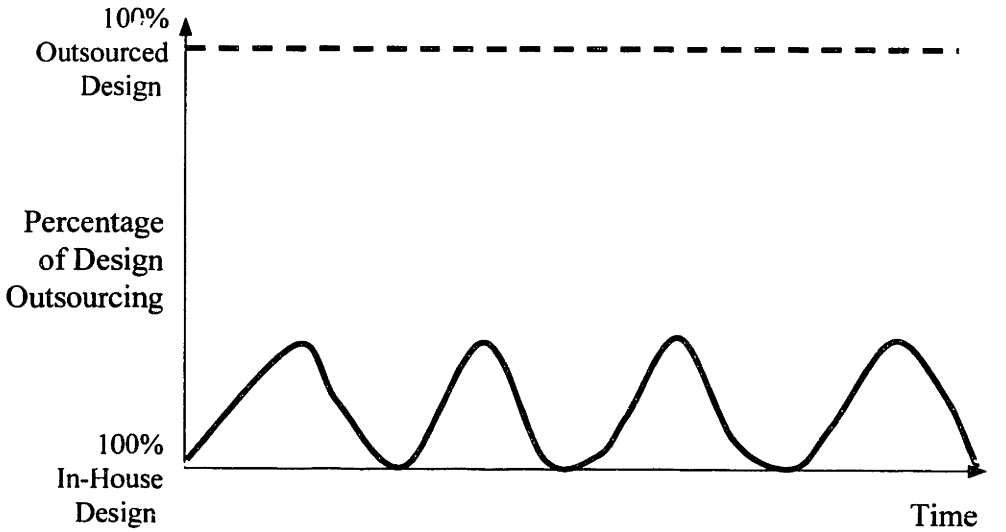

Figure 6-2: Exploratory Design Outsourcing

In effect, this is a knowledge trade. Your firm will surrender knowledge about its product and suppliers for new knowledge in design practices, product technology and another network of suppliers. This same effect can be achieved from just using design outsourcing for those instances where demands on internal resources are too great (reference paragraph 2.2.1.2 Resource Limitations). However, as the system dynamics model points out, not managing the internal design and outsourced design balance is difficult given the number of reinforcements to increase design outsourcing.

6.2.1.2 Incremental Product Design Outsourcing

In this approach, the level of design outsourcing is held relatively stable, but the products that are outsourced are incremental improvements to current products. Three benefits are reaped from this approach. First, the internal design resources are reduced and limited to working on the newest projects, keeping their morale and interest high. Secondly, the knowledge gained from working with design suppliers provides the same benefits as exploratory design outsourcing. Lastly, the outsourced knowledge during these engagements should be less competitive than the brand new product design work, reducing the risk of knowledge transfer. This practice is shown in Figure 6-3: Incremental Product Design Outsourcing.

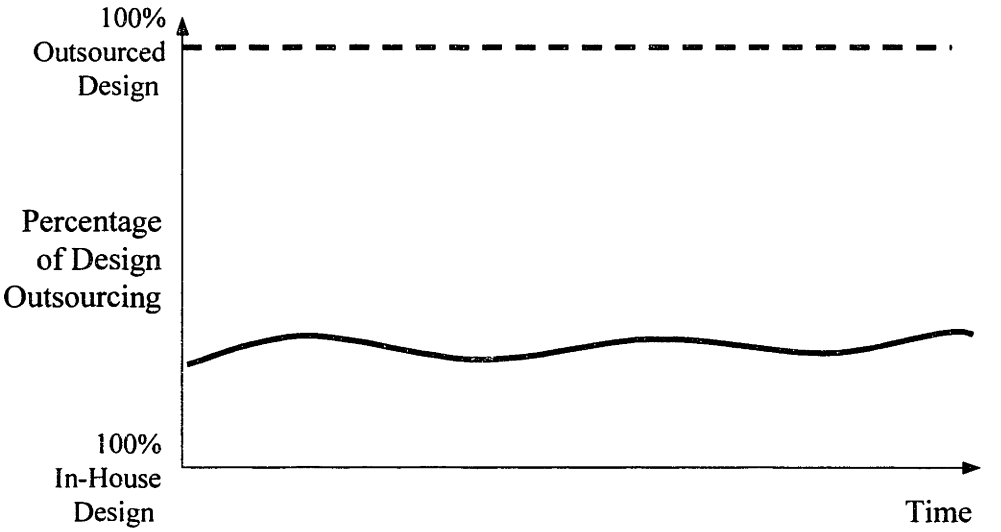

Figure 6-3: Incremental Product Design Outsourcing

6.2.2 Become a Design Supplier

A role reversal can provide some of the same benefits to the corporation that the product development firms currently enjoy. Specifically, if the knowledge audit of your corporation

shows a knowledge kernel cannot be adequately supported by current internal design activities, then consider providing a design service for other companies, not necessarily in the same industry. For example, consider the earlier mentioned case of Matsushita's compressors that are used in many refrigerators other than their own. If its internal design staff were supporting just Matsushita's products, it would have difficulty maintaining technology leadership for this kernel.

A true knowledge kernel could be used as an attractant to expand into other businesses. Knowledge transferred during design engagements with other corporations will benefit your internal design staff with new approaches and applications. Borrowing from 9th Wave, "earn while you learn."[125]

6.3 Defense: Outsource Design Intelligently

If a strategic decision is made to outsource the design of your product(s) than the following recommendations will help reduce the risks associated with this practice. The reason for additional caution in design outsourcing is based on what has been learned about the uniqueness of design as a rich field of knowledge and as a unique instrument in transferring knowledge. The commonly touted approach for outsourcing success is to treat your suppliers as an extension of your own company and to focus on building a relationship.[126] I agree as long as critical industry and knowledge defensive analyses and measures have been executed.

6.3.1 Retain Your Knowledge Kernel

If you have identified a knowledge kernel, it makes sense to retain and nurture that kernel as described in the previous section. By not outsourcing the design of a knowledge kernel, you are more likely to protect the knowledge that provides competitive advantage. However, it is still likely that the design supplier will learn something about the knowledge kernel as part of the design engagement. Even in a modular architecture, the design process is unique in its needs to understand a larger sense of the product to effectively integrate all the knowledge needed to solve the design problem. This is also an area where perhaps the best defense is a great offense – make the investments and renew your knowledge kernel to stay a step ahead of the competition.

---

[125] Ed Gilchrest, Interview at 9th Wave Inc. (Southbury, CT: March 4, 2000).

[126] Robert B. Handfield, Daniel R. Krause, Thomas V. Scannell, and Robert M. Monczka, "Avoid the Pitfalls in Supplier Development," Sloan Management Review 41 (Winter 2000), pp. 37-49.

6.3.2 Product versus Component Outsourcing and Knowledge Intensity

Outsourcing the design of a component or subassembly instead of an entire product can relieve the demands on internal resources, partially limit knowledge transfer, and still help in transferring knowledge back to your corporation. For example, outsourcing the design of a machined part for an automobile will transfer much less knowledge about the auto's design than outsourcing the entire chassis. But, as the system dynamics model showed in Chapter 5, this practice can accelerate to more design outsourcing as well as more knowledge transfer if not carefully monitored for its alignment with the core competence of the corporation.

As the knowledge intensity of a product grows, product modularization can be used to limit the transfer of total product knowledge. By making module interfaces more discrete and less encompassing, the need for intense design collaboration between your corporation and your design supplier is lessened. However, if taken too far, this approach limits the potentially valuable input that a knowledgeable supplier can provide during the early stages of design.

6.3.3 Maintain the Knowledge To Be a Smart Buyer

As the purchaser of any service that is critical to your competitive advantage, such as the design of your product, you must be a smart buyer. However, the design of a product entails the integration of tacit and explicit knowledge. Even if the knowledge is explicit and codified, an understanding of the product knowledge is required for an equal collaboration. In Kimzey's survey of Japanese and U.S. outsourcing practices, the respondents agreed that effective outsourcing of technology requires the internal expertise to "understand, anticipate, and encourage the development of technology by others. The implication is that the technical staff will have to add new management skills but their technical know-how needs to be continuously updated and strengthened and not allowed to atrophy."[127]

Maintaining this knowledge requires knowledge management and a "learn by doing" approach to applying the knowledge. I believe that this is best accomplished through an internal design staff, even if small. By keeping knowledge fresh internally, you propagate the important knowledge that is gleaned from your engagements with design suppliers.

---

[127] Charles H. Kimzey, Jr., "Outsourcing Technology for New Product Development: A U.S.-Japan Study of Technology Strategy," Ph.D. Dissertation in Management of Technology, (Nashville, TN: Vanderbilt University, 1998), pp. 135-136.

In the case of Crown Equipment Corporation, a designer and manufacturer of industrial lift equipment, their multi-decade long relationship with the design consultancy RichardsonSmith (RS) was successful because Crown Equipment maintained their own engineering design capability, though no industrial design capability. With an internal design base, they were able to bring to the design different, but knowledgeable perspectives.[128] In the 1990s, when the relationship with RichardsonSmith became strained, they were able to bring design work back in-house.

6.3.4 Use Field of Use, Intellectual Property, Non-Disclosure Agreements

For design outsourcing to be effective, the relationship between the design firm and the client must be one of "intense collaboration."[129] It is this same collaboration that leads to the transfer of knowledge. Product Genesis talked about how "hairy" the negotiations for the "field of use" usually were at the beginning of a product development engagement.[130] By negotiating to the widest possible field of use you can restrict the design supplier's development of competing products in your market space.

Intellectual property, including patents, copyrights, and trademarks, should be used to defend and protect design and product knowledge. Ignoring this tactic can be costly. For example, in 1991 Reebok International sued Design Continuum Inc. after unveiling a new air bladder baseball glove line called the AirFlex it had designed for Spalding Sports Worldwide. Reebok contended that Design Continuum had used proprietary technology it had developed for Reebok in the Pump sneaker. The case was soon settled with Spalding able to continue selling its glove. The judge most likely found that the contract between Reebok and Design Continuum did not specifically prohibit applying the air bladder technology elsewhere.[131] There is no surefire way to prevent people from walking away with the knowledge that they have in their heads. Non-disclosure agreements and other restrictions may not stop the transfer of knowledge, but they can slow it down.

---

[128] Karen Freeze and Gary Pisano, "Crown Equipment Corporation: Design Services Strategy," Design Management Institute Case Study 9-991-031 (Boston, MA: Harvard Business School Press, 1991).
[129] Brian Vogel, Interview at Product Genesis (Cambridge, MA: March 6, 2000).
[130] Brian Vogel, Interview at Product Genesis (Cambridge, MA: March 6, 2000).
[131] Justin Martin, "What Fits Better than a Glove?," Across the Board, 29 (September 1992), pp. 40-46.

6.3.5 Using Gatekeepers To Control Information Flow

Using a gatekeeper to limit the flow of information in an outsourced design effort is one possible method to control critical or competitive sensitive information. However, this can only be effective if the access to information is limited and tightly controlled, which might be highly undesirable in design collaboration. Also, the effectiveness of trying to limit the flow of information ultimately comes down to individuals and their discipline or loyalty.[132] If the main reason you are outsourcing the design is to gain speed in product development, any withholding of knowledge may impede that development, although gatekeepers can become the points of knowledge responsible for disseminating knowledge from the design engagement back into the corporation.

6.3.6 Carefully Select Your Supplier

> "We cannot enter into alliance with neighboring princes until we are acquainted with their designs."
>
> Sun Tzu[133]

Because of knowledge transfer, selecting a company for design outsourcing presents potential risks not seen in other outsourcing. Before deciding on a design supplier you should attempt to establish its strategic intent. Is the potential supplier a large contract manufacturer that is supplying competitor's products? If it is already manufacturing its own designs, in what industry has it been building knowledge assets? Answering these questions may unveil a strategic intent that is contrary to your long-term competitive advantage.

When competitors in the same industry ally with one another for product development, these are often alliances born out of a need for risk sharing and resource availability, not for a desire to eventually disband their design departments. But this can create unforeseen difficulties in managing knowledge transfer. For example, Boeing Military Aircraft and Missiles Group and Lockheed Martin are teamed on the F-22 Raptor fighter aircraft but are fierce competitors on the Joint Strike Fighter (JSF). This makes for difficult arrangements at Lockheed Martin in Fort

---

[132] Gary Hamel, Yves L. Doz and C.K. Prahalad, "Collaborate with Your Competitors – and Win," Harvard Business Review (January – February 1989), pp. 137-138.

[133] Sun Tzu, The Art of War, James Clavell, ed., (New York: Dell Publishing, 1983), p. 68.

Worth, TX where Lockheed JSF prototype development is occurring in the same facility as the F-22.[134]

The best defensive maneuver is outsourcing to a design supplier or suppliers whom have shown through their behavior over time that they warrant your trust, while at the same time limiting strategic knowledge transfer risks.

6.4 Manage the Buyer-Supplier Relationship

Each of the possible design sources, described in paragraph 4.4.7 Outsourcing Methods, or Who's Your Partner?, represents unique challenges to managing outsourced design. The responsibility for this task rests with both parties and begins with identifying a single individual on each side that is responsible for the outsourcing engagement outcome – the relationship managers – who become part of an oversight council. The requirements and methodology for knowledge flow between the supplier and the buyer should be clearly articulated. Greaver recommends weekly meetings between the relationship managers to discuss operational issues and monthly meetings for performance reviews.[135] This recommendation agrees with the interviewed product development firms and their description of their relationships with their clients. Even if the firms did not meet that frequently with their clients, weekly reports provided a flow of information back to the client.

Beyond simply good management practice, the reason for emphasizing the frequent interchange between the parties is to ensure knowledge is appropriately transferred. Required knowledge for the design must be available to the supplier, while knowledge transfer from the engagement will not be effectively transferred back to the corporation unless there is a continuous exposure. Personal communication between the parties is most effective for the corporation to gain the tacit and explicit knowledge in a product design engagement.

---

[134] Source: Tour by the author of Lockheed Martin, Fort Worth, TX, February 1998.

[135] Maurice F. Greaver II, Strategic Outsourcing: A Structured Approach to Outsourcing Decisions and Initiatives (New York: AMACCM, 1999).

6.5 The Catch-22

Unfortunately, for some industries, the design outsourcing dilemma may be a lose-lose game. Corporations that retain most design work in-house may be unable to compete in the short-term with firms that leverage design collaborations with many firms. These corporations may find themselves surrendering to the faster, flexible corporations that use outsourced design and module assembly techniques. Meanwhile, as supplier knowledge grows, the supplier's willingness to enter into the market and outsource the manufacturing of its designs will bring us full circle to new corporations and manufacturers replacing the old.

6.6 A Final Recommendation for an Aircraft Manufacturer

This thesis began by recounting the decision of an aircraft manufacture to outsource the airframe subsystem design of a new aircraft. The resulting investigation of the many dependent variable interactions in design outsourcing provides evidence that long-term strategic reactions can adversely affect the company's ability to innovate and remain competitive in the domain of its outsourced knowledge. Fundamentally, if a company does not practice what is needed for its ability to innovate in the future, it will have difficulty competing.

Empirical evidence from Iansiti has shown the importance of competitive advantage born from integration.[136] Because the airframe subsystem is the integration discipline for an aircraft, maintaining this discipline for a competitive future while outsourcing the design is a contradiction. However, there is evidence that benefits can be reaped from careful design outsourcing, including an enhanced ability to innovate from more diverse knowledge sources, provided the knowledge management practices are in place to capture that knowledge. Because of the long delays in a long clockspeed industry such as the aircraft industry, the effects from this practice may take many years to play out. In the meantime, watch what happens in the computer industry, the fruit fly of industry biological species.

6.7 Chapter Summary

Design outsourcing can be leveraged offensively for strategic advantage but doing so revolves around understanding the knowledge intensity, knowledge kernels and knowledge

---

[136] Marco Iansiti, Technology Integration: Making Critical Choices in a Dynamic World, (Boston, MA: Harvard Business School Press, 1998).

management practices of your firm. The knowledge that can be learned through exploratory or incremental product design outsourcing can help refresh creativity and design practices in an internal design organization.

From a defensive perspective, protecting knowledge kernels or limiting knowledge transfer during design outsourcing is difficult. A better approach is to acknowledge that knowledge will be transferred to the design supplier and act accordingly. Retain and develop your product's knowledge kernel. Retain sufficient design knowledge to be a smart buyer of design services. Build legal barriers to prevent its competitive use while leveraging modularization or gatekeepers can limit the access to key knowledge.

The ability of a firm to sustain competitive advantage while employing design outsourcing remains to be seen. The catch-22 is that by not using design outsourcing in some fashion, a corporation may also not be able to sustain competitive advantage. Managing this quandary must be done with a knowledge management perspective.

Chapter 7. Summary

The quest for this thesis was to uncover the strategic implications of design outsourcing. This quest was brought about from my own bias towards the importance of design to the long-term viability of a corporation that is product-based. Without successful product design, competitive advantage in the market place cannot be sustained. For example, Dell Computer's continued ability to reap economic rent from its direct-to-consumer business model is only possible because it has a good product to sell. Similarly, Apple Computer's rejuvenation in 1999 can be correlated to the differentiating design of its iMac personal computer.

Interestingly, an increasing number of companies are looking outside their firms to provide the design of their products. Companies that have already outsourced the manufacturing of their products have welcomed the growing offerings of some suppliers to do the design of the products as well. Design process changes as well as changes in the business environment have contributed to an increasing willingness and ability to outsource design. The reasons given for design outsourcing include cost savings, internal resource and skill limitations, a desire for greater focus on some other part of the value chain, political motivations, a search for greater innovation, and sometimes, the hope to learn something from their supplier. The results from this thesis suggest this advice to companies chasing design outsourcing for competitive advantage – do so carefully and knowingly of the risks and benefits, particularly with regards to the transfer of knowledge.

Design is a unique harbinger of the company's product knowledge. By thinking about the knowledge intensity of the product – the amount of tacit and explicit knowledge the product embodies to solve the design problem – a corporation can begin to consider the strategic implications of transferring this knowledge. The knowledge intensity of a product is influenced by the technology and systems integrated into the product and the testing and field support knowledge that validates it. The potential ramifications of knowledge transfer are more important if the product embodies a corporation knowledge kernel – the part or product that embodies the knowledge that is core to the corporation.

Both explicit and tacit knowledge about the design reasoning and the product are exchanged during the collaboration that takes place during a design. The greater the knowledge intensity of the product, then the greater the amount of collaboration that will be required. This

collaboration – the doing of the design – is the central mechanism for transferring knowledge between the design supplier and the corporation. When completed, the product is a physical embodiment of all the design decisions, knowledge and innovation focused to solve the problem that originated the product.

Benefits and risks from design outsourcing are also linked to this knowledge transfer. A product development firm, such as the ones interviewed for this thesis, is able to work with many different companies and product designs. This diversity of knowledge can contribute to greater innovation and advantageous knowledge transfer to the corporation provided the corporation properly focuses on knowledge management during design collaboration. Knowledge transfer, depletion and loss can also lead to supplier dependency, a long-term loss of product innovation and a ultimately an increased likelihood of new industry entrants.

Current outsourcing frameworks do not delve into the specific risks and benefits associated with design outsourcing because of their historical derivation from operations management. By applying a system dynamics modeling approach, this thesis supplements these frameworks to help the corporation decide an approach for design outsourcing. This approach also identifies that the reinforcing feedback loops for outsourcing outnumber balancing loops by eight to three, implying that once design outsourcing is begun, it will increase over time. This finding emphasizes the caution that firms should apply when using the strategic tool of design outsourcing while searching for its benefits.

In addition to creating a knowledge foundation for design outsourcing, two styles of design outsourcing are offered to offensively counter the risks of design outsourcing: exploratory and incremental design outsourcing. In either instance, the corporation must acknowledge that knowledge transfer about its products will take place, but it can reap the benefit of innovative thinking and other knowledge for its next designs. In a third recommendation, the corporation becomes the design supplier, to taking advantage of being paid while learning from its clients. In each case, the corporation can be thought of as fertilizing its internal knowledge garden for design.

Defensively, the corporation must outsource intelligently by understanding its knowledge assets and ensuring these are not given away. Legal, organizational and product architectural means can be employed to protect the use or dissemination of knowledge. But perhaps the best

defense is knowing as much about the design supplier as possible. Long-term interactions and the creation of trust will also provide greater visibility into the supplier's strategic intent.

Although there is an expanse of work that explores design, knowledge management, outsourcing and strategy individually and in some combinations, it is hoped that this work provides an invitation to explore more empirically the relationship of design outsourcing to sustaining competitive advantage. The concepts of knowledge intensity and knowledge kernels can also be developed further. For example, this thesis has not attempted to unitize knowledge intensity. By identifying and dissecting the knowledge domains and the efforts that are integrally involved in the design of a product, this concept can be refined.

The system dynamics model has identified the many interacting variables and feedback loops that drive knowledge transfer and reinforce the practice of design outsourcing. Completing the mathematical modeling of this system requires the notoriously difficult quantification and empirical measurement of knowledge, market and product variables – something that is well beyond the scope of this thesis and likely too controversial to be applied. The greatest benefit comes from seeing the reinforcing and balancing feedback loops and contemplating how they may be influenced in a particular design outsourcing decision.

For companies contemplating or currently involved in outsourcing the design of their products, perhaps the simplest message that should be taken away is that you are outsourcing knowledge. Recognizing this fact and ensuring that the resulting strategic implications are an integral part of your design sourcing decision are keys to ensuring that the strategic risks are minimized and the benefits are maximized.

Bibliography

"A Decade of Design: How Great Products Can Boost the Bottom Line." Business Week 29 November 1999: 90.

Allen, Thomas J. Managing the Flow of Technology: Technology Transfer and the Dissemination of Technological Information with the R&D Organization. Cambridge, MA: MIT Press, 1977.

Baldwin, Carliss Y. and Clark Kim B. Design Rules: The Power of Modularity. Cambridge, MA: MIT Press, 2000.

Bleck, Jim. Personal interview. 8 Mar. 2000.

Bohn, Roger E. "Measuring and Managing Technological Knowledge." Sloan Management Review 36 (Fall 1994): 61-73.

Bruce, Margaret and Barny Morris. "Managing external design professionals in the product development process." Technovation 14 (November 1994): 585-599.

Callaway Cars web site. http://www.callawaycars.com.

CATIA web site. http://www.catia.com.

Chazan, Guy. "Six Top Designers Quit Russia's MiG Jet Maker: Future Is in Doubt At State-Owned Aircraft Exporter." Wall Street Journal 2 Dec. 1999, A17.

Chesbrough, Henry W. and David J. Teece. "When is Virtual Virtuous? Organizing for Innovation." Harvard Business Review. 74 (Jan.- Feb. 1996): 65-71+.

Christensen, Clayton M. The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail. Boston, MA: Harvard Business School Press, 1997.

Core77 web site. http://www.core77.com.

Davenport, Thomas H., and Laurence Prusak. Working Knowledge: How Organizations Manage What They Know. Boston, MA: Harvard Business School Press, 1998.

Dean, Paul. "Behind the Wheel: Callaway's C12 is a Super Car Built for the Highway, if Not the Raceway." Los Angles Times 26 Aug. 1999, W-1.

Defense Systems Daily web site. http://defence-data.com.

Domberger, Simon. The Contracting Organization: A Strategic Guide to Outsourcing. New York: Oxford University Press, 1998.

"Fast Car, Fast Development." Automotive Manufacturing & Production 1 May 1999: 48.

Fine, Charles H. Clockspeed: Winning Industry Control in the Age of Temporary Advantage. Reading, Mass: Perseus Books, 1998.

Freeze, Karen, and Gary Pisano. "Crown Equipment Corporation: Design Services Strategy." Design Management Institute Case Study 9-991-031. Boston, MA: Harvard Business School Press, 1991.

Gilchrest, Ed. Personal interview. 4 Mar. 2000.

Goodrich, Kristina. "First-Ever Survey Projects Dramatic Growth in U.S. Industrial Design Employment." Industrial Designers Society of America web site. http://www.idsa.org/.

Greaver, Maurice F., II. Strategic Outsourcing: A Structured Approach to Outsourcing Decisions and Initiatives. New York: AMACOM, 1999.

Hamel, Gary, and C. K. Prahalad. Competing for the Future. Boston, MA: Harvard Business School Press, 1994.

Hamel, Gary, Yves L. Doz and C. K. Prahalad. "Collaborate with Your Competitors – and Win." Harvard Business Review. 67 (Jan.-Feb. 1989): 133-139.

Handfield, Robert B., et al. "Avoid the Pitfalls in Supplier Development." Sloan Management Review 41 (Winter 2000): 37-49.

Iansiti, Marco. Technology Integration: Making Critical Choices in a Dynamic World. Boston, MA: Harvard Business School Press, 1998.

Kimzey, Charles H. Jr. "Outsourcing Technology for New Product Development: A U.S.-Japan Study of Technology Strategy." Ph.D. Diss. Nashville, TN: Vanderbilt University, 1998.

Lehnerd, Alvin P. "Revitalizing the Manufacture and Design of Mature Global Products." Technology and Global Industry: Companies and Nations in the World Economy. National Academy Press, 1987. 49-64.

Leonard, Dorothy. Distributed class material from Harvard Business School Course 2170: The Knowledge Lab 8 Sep. 1999.

Leonard, Dorothy. Wellsprings of Knowledge: Building and Sustaining the Sources of Innovation. Boston, MA: Harvard Business School Press, 1998.

Martin, Justin. "What Fits Better than a Glove?" Across the Board, 29 (Sep. 1992): 40-46.

Matt, Brian J. Telephone interview. 10 March 2000.

Metcalfe, Bob. "Forward Integration Looks Like the Latest Trend." Infoworld 15 (8 Nov. 1993): 63.

Noehren, William L. Development and Empirical Investigation of a Boundary Object Richness Scale for Product Development Teams. Masters Thesis, Alfred P. Sloan School of Management, Massachusetts Institute of Technology, June 1999.

Nonaka, Ikujiro. "The Knowledge-Creating Company." Harvard Business Review. 69 (Nov. – Dec. 1991): 96-104.

Oster, Sharon M. Modern Competitive Analysis. 3rd ed. New York: Oxford University Press, 1999.

OXO web site. http://www.oxo.com.

Pannozzo, Anthony. Personal interview. 10 March 2000.

Pine, B. Joseph II. Mass Customization: The New Frontier in Business Competition. Boston, MA: Harvard Business School Press, 1993.

Pinelli, Thomas E., et al. Knowledge Diffusion in the U.S. Aerospace Industry: Managing Knowledge for Competitive Advantage, Part A. Greenwich, CT: Ablex Publishing, 1997.

Prahalad, C. K., and Gary Hamel. "The Core Competence of the Corporation." Harvard Business Review 68 (May-Jun. 1990): 79-90.

Product Insight telephone interview. 8 March 2000.

Rothstein, Arnold J. "Outsourcing: An Accelerating Global Trend in Engineering." ASEM Engineering Management Journal 10 (March 1998): 7-14.

Sanderson, Susan Walsh, and Mustafa Uzumeri. Managing Product Families. Chicago, IL: Irwin/McGraw-Hill, 1997.

Schweizer Aircraft web site. http://www.sacusa.com.

Slywotzky, Adrian J. Value Migration: How to Think Several Moves Ahead of the Competition. Boston, MA: Harvard Business School Press, 1996.

Sperling, Daniel. "Managing Innovation: Supercar Shows How Partnerships Can Falter." Inside R&D 9 Apr. 1997: 4.

"Suppliers Expect Bigger Role in Powertrains." Automotive News 3 August 1998: 141.

Thurm, Scott. "Solectron Becomes a Force in 'Stealth Manufacturing.'" Wall Street Journal 18 Aug. 1998, B4.

Tunisini, Annalisa and Antonello Zanfei. "Exploiting and Creating Knowledge Through Customer—Supplier Relationships: Lessons From a Case Study." R&D Management 28 (1998): 117.

Tyre, Marcie J., and Eric von Hippel. "The Situated Nature of Adaptive Learning in Organizations." Organization Science 8 (Jan.-Feb. 1997): 71-83.

Tzu, Sun. The Art of War. James Clavell, ed. New York: Dell Publishing, 1983.

Ulrich, Karl T., and Steven D. Eppinger. Product Design and Development. New York: McGraw-Hill, 1995.

Utterback, James M. Mastering the Dynamics of Innovation. Boston, MA: Harvard Business School Press, 1996.

Vogel, Brian. Personal interview. 6 March 2000.

THESIS PROCESSING SLIP

FIXED FIELD: ill. _____ name _____

index _____ biblio _____

▸ COPIES: (Archives) Aero (Dewey) Eng Hum

Lindgren Music Rotch Science

TITLE VARIES: ▸☐ _____

NAME VARIES: ▸☒ Leigh

IMPRINT: (COPYRIGHT) _____

▸ COLLATION: 108 P

▸ ADD: DEGREE: _____ ▸ DEPT.: _____

SUPERVISORS: _____

NOTES:

cat'r: date:

page:

▸ DEPT: Mgt ▸ 207

▸ YEAR: 2000 ▸ DEGREE: S.M. M.O.T.

▸ NAME: GRANT, Peter L.