

**Collaborative Design for Supply Chain:  
Including Strategic and Tactical Supply-Chain Considerations in  
Product Design & Development**

by  
**Esteban A. Guerrero Jaimes**

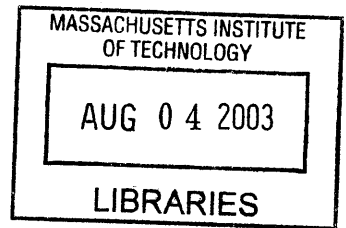
B.S., Mechanical & Electrical Engineering,  
Monterrey Institute of Technology (ITESM), 1995

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

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

In Conjunction with the Leaders for Manufacturing Program at the  
**Massachusetts Institute of Technology**  
May 2003

© 2003 Massachusetts Institute of Technology  
All rights reserved



Signature of Author.....  
Sloan School of Management, Department of Mechanical Engineering  
May 9, 2003

Certified by.....  
Charles H. Fine, Thesis Advisor  
Sloan School of Management

Certified by.....  
David Hardt, Thesis Advisor  
Department of Mechanical Engineering

Accepted by.....  
Margaret C. Andrews, Executive Director of Master's Program  
Sloan School of Management

Accepted by.....  
Ain A. Sonin, Chairman, Department Committee on Graduate Studies  
Department of Mechanical Engineering

(This page intentionally left blank.)



**Collaborative Design for Supply Chain:  
Including Strategic and Tactical Supply-Chain Considerations in  
Product Design & Development**

by

**Esteban A. Guerrero Jaimes**  
B.S., Mechanical & Electrical Engineering,  
Monterrey Institute of Technology (ITESM), 1995

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

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

**ABSTRACT**

The importance of design decisions in manufacturing has been long known. Within the last ten years, as supply-chain management became the new topic in vogue, it became only natural to extend some concepts previously applied to the manufacturing line to the entire supply chain: reducing lead-time, cost, and inventory levels, while maintaining or increasing customer service levels.

The cases in the electronics industry studied in this research show a tendency to consolidate efforts in supply-chain design and supply-chain management to produce an enterprise-wide, end-to-end supply-chain strategy. Product development processes should therefore be modified and design engineers engaged in supply chain-related decisions. In short, it is important that product development teams understand the supply-chain performance consequences of their decisions.

This project not only faces the challenge of influencing organizational behavior, however; it faces the challenge of developing the concepts, guidelines and tools that it intends to instill, given that no prior work amalgamates these diverse concepts. Design for Supply Chain (DFSC) fills this void in order to enable organizations to gain or sustain competitive advantage.

Thesis Advisors: Charles H. Fine, Chrysler LFM Professor of Management, Sloan School of Management; David Hardt, Professor of the Department of Mechanical Engineering.

(This page intentionally left blank.)

A mis padres;

a Ame y a Isaac;

a mi papabel, a mi abue,  
a mis tías, tíos, primos y primas;

a Ana Rosa, los Carlos, Fernando, Miss Normie y Paco

a todos ellos, por sus sacrificios, enseñanzas y apoyo, gracias.

---

To Bill, Brian, Carla, Jason, Jonathan, Laura, Leoncio, Mack, Monica, Rick, Stephan, Ted,  
and my Sloanie friends,  
for making these two years invaluable;

to the Leaders for Manufacturing Fellows program staff and friends,  
for making these two years possible;

to my colleagues at work,  
for the teachings and the challenges during the research;

to Professors Hardt and Fine,  
for ensuring that I learn my final lessons at MIT;

Thanks.

(This page intentionally left blank.)

<b>TABLE OF CONTENTS</b>	<b>page</b>
<b>1 INTRODUCTION AND OVERVIEW.....</b>	<b>9</b>
1.1 Overview of This Thesis.....	9
1.2 Design for Supply Chain.....	10
1.3 Problem Statement.....	12
<b>2 BENCHMARKING AND REVIEW OF SOME EXISTING LITERATURE AND METHODOLOGIES.....</b>	<b>15</b>
2.1 Chapter Introduction.....	15
2.2 Clockspeed and 3-Dimensional Concurrent Engineering (3DCE).....	15
2.3 Work Done at or in Collaboration with Hewlett-Packard.....	20
2.4 Multi-Attribute Tradespace Exploration with Concurrent Engineering (MATE-CON) .....	22
2.5 Quality Function Deployment (QFD) .....	24
2.6 Summary.....	26
<b>3 RECOMMENDATIONS.....</b>	<b>27</b>
3.1 Chapter Introduction - The 14 Recommendations.....	27
3.2 No. 1, 14 – Perform Product/Process/Supply-Chain Design Before Every Major Product Launch. Include Technology Roadmap Analysis and Competitor & Supplier Assessment.....	29
3.3 No. 2 – Enhance Supply-Chain Collaboration with All Stakeholders Continually.....	34
3.4 No. 3 – Determine Optimal Variety of SKUs.....	35
3.5 No. 4 – Assess Total Supply-Chain Costs and Lead-Times.....	38
3.6 No. 5 – Ensure Product-Component Life-Cycle Match.....	39
3.7 No. 6 – Implement Cost Avoidance.....	40
3.8 No. 7, 12 – Apply Part & Enclosure Reuse and Commonality (Including Universalization) Principles When Selecting Components.....	43

3.9	No. 8, 13 – Select Best Design Through a Utility Vs. Costs Vs. Lead-Time (or TTM) Analysis at a Formal Cross-Functional Design Review.....	45
3.10	No. 9 – Apply DFA, DFM, DFT+DFR <sup>2</sup> +DFE Guidelines Earlier.....	51
3.11	No. 10 – Begin DFL Analysis Earlier.....	52
3.12	No. 11 –Expand the Application of Postponement.....	53
4	A FRAMEWORK FOR IMPLEMENTATION.....	55
4.1	Chapter Introduction.....	55
4.2	A Framework to Understand the 14 DFSC Recommendations.....	55
4.3	A Framework to Introduce and Implement the 14 DFSC Recommendations..	61
4.4	A Framework to Drive Implementation of DFSC.....	64
5	THE ORGANIZATIONAL CHALLENGE.....	66
5.1	Using the Three Lenses on Organizational Processes.....	66
5.2	Leading the Change Process.....	67
5.3	Evaluation and Recommendations.....	71
6	FUTURE RESEARCH.....	73



# 1 INTRODUCTION AND OVERVIEW

## 1.1 Overview of This Thesis

The importance of design decisions in manufacturing has been long known. First, it became important to specify the dimensional tolerances of assembly parts for the manufacturer to ensure proper fit, which implied the need for standard drawings and encoding. Firms could no longer hand-make each part to accommodate geometric variability. Later in the 80's, concepts such as Design for Manufacturability (or Manufacturing; DFM) and Design for Assembly (DFA) were introduced when the accumulated experience of manufacturers pointed to the need to modify the design of parts or entire products to (1) guarantee easy, efficient assembly and manufacture of parts and therefore (2) reduce waste, excessive unforeseen costs and lead-times.

Within the last ten years, as Supply-Chain Management (SCM) became the new topic in vogue, it became only natural to extend some concepts previously applied to a manufacturing line to the entire supply chain: reducing lead-time, cost, and inventory levels, while maintaining or increasing quality and customer service levels. Doing so would imply then that all an organization would have to do to improve its designs is apply DFA, DFM and other Design for X (DFx) guidelines to higher-level processes, taking into account the participation of the entire supply base and even of the customers. However, extensive work that will be discussed later would suggest that there are other aspects of SCM that are not apparent in any DFx guidelines so far. Furthermore, this previous work and the observations made during the course of this project suggest that there are even strategic aspects to SCM that have not been accounted for before.

The recommendations put forth in this thesis, however, are not exclusive of any particular product development process. In fact, this thesis does not intend to devise a new process. Be it a pure "Multi-Attribute Tradespace Exploration with Concurrent Engineering" (MATE-CON) process or Quality Function Deployment (QFD), they all can benefit from the realization that, from a supply-chain performance perspective, there are certain requirements that are usually ignored by product development teams.

“Although the supply-chain management label is relatively new, the problems considered are not.”<sup>1</sup> With the advent of the Japanese quality and management techniques and the spreading use of analytics in operations management, manufacturing began to benefit from forecasting, aggregate planning, inventory control, push-pull production systems, etc. “So, what is new about SCM? The simple answer is that SCM looks at the problem of managing the flow of goods as an integrated system.”<sup>2</sup> In other words, modifying the design to include fewer steps or components will benefit the inventory levels, safety stock levels, and lead-times of one factory, but when these effects are enhanced by the complexity of a supply chain or supply network, these effects become essential cost drivers that can make the difference between profit and loss in industries where profit margins are low. “While important and useful in many contexts, simple formulas such as the EOQ [economic order quantity] are unlikely to shed much light on effective management of complex supply chains.”<sup>3</sup> Thus supply-chain analysis requires other tools and approaches.

As an initial disclaimer note, truly end-to-end supply chain should include reverse logistics (e.g. for activities such as taking back product, returns, recycling, servicing, etc.), but the scope of this project only included what is commonly considered a generic Product Design & Development (PDD) process, as depicted in Figure 1.

## 1.2 Design for Supply Chain

Several definitions shed some light on the true meaning of “Design for Supply Chain;” among those, here are three:

- “Designing the right supply chain for each product, and designing the right product for each supply chain”<sup>4</sup>
- “Low-variability input, high-variety output”<sup>5</sup>

---

<sup>1</sup> Nahmias, Steven, Production and Operations Analysis, 4<sup>th</sup> ed., McGraw-Hill Irwin, NY, 2001, p. 305.

<sup>2</sup> Nahmias, Steven. Ibidem.

<sup>3</sup> Nahmias, Steven. Ibidem, p. 306.

<sup>4</sup> Communicated during an interview in the initial stages of the research.

<sup>5</sup> Comment by Prof. Dan Whitney on July 31, 2002.

- “A successful new product design must not only meet the targeted functional performance requirements, but must meet numerous other requirements to satisfy customers over the product's lifecycle. It must be testable, manufacturable, sustainable, and be adaptable to different supply-chain options.”<sup>6</sup>

## Scope of this research project

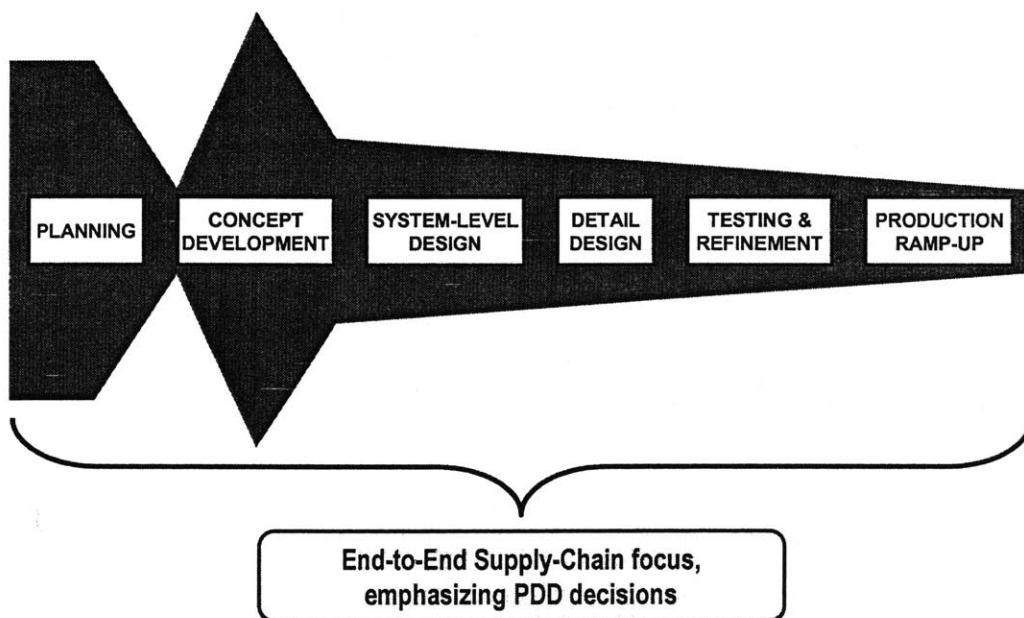


Figure 1 – Scope of this research. The diagram presented is adapted from “The generic product development process,” by Ulrich and Eppinger.<sup>7</sup>

However, none of these seemed to capture the strategic-yet-tactical aspect of DFSC uncovered by this project. Based on the above, the following definition has been produced:

“DFSC is the set of design guidelines, tools and objectives that help us differentiate ourselves (our products) to gain or sustain competitive advantage.”<sup>8</sup>

<sup>6</sup> Anonymous.

<sup>7</sup> Ulrich, Karl T. & Steven D. Eppinger, *Product Design and Development*, 2<sup>nd</sup> ed., McGraw-Hill, 2000.

In this way, DFSC improves supply-chain performance—that is, operational efficiency and strategy.<sup>9</sup>

### 1.3 Problem Statement

As the electronics industry decided to consolidate efforts in supply-chain design and supply-chain management to produce an enterprise-wide, end-to-end supply-chain strategy, it has realized that its PDD process has to be modified and that design engineers have to be engaged in supply chain-related decisions. The current PDD does not take into account various supply chain-related inputs, some of them strategic, like the concepts and analyses of 3-Dimensional Concurrent Engineering (3DCE, i.e. the concurrent design of product, process and supply chain)<sup>10</sup>; some of them rather concrete, like the modification of packaging to fill up pallet capacity and reduce freight costs. A few examples help describe the scenario better:

- Selecting components. Engineers lack a process that allows them to select components in a way that (1) minimizes the total number of components per product and across product lines, (2) minimizes the number of versions of components, and (3) modifies the system design to accommodate common components and enclosures.
- Creating part numbers. Because qualification procedures may be too cumbersome to be willingly followed every so often, when engineers want to work with a new vendor, they tend to avoid having this new vendor's components qualified for all products the component type is used for; it is simply easier to create a new part number for the specific vendor-component combination. Doing so, however,

---

<sup>8</sup> Although many people collaborated for the concepts inherent in this definition, most of the wording is Prof. Fine's.

<sup>9</sup> Michael Porter argues that "Operational Effectiveness (OE) and Strategy are both essential to superior performance, but they work in very different ways: OE means performing similar activities better than rivals do. Strategic positioning means performing different activities from rivals' or performing similar activities in different ways." OE is not sufficient; this condition is the result of: "Rapid diffusion of best practices—fierce competition produces absolute improvement in OE, it leads to relative improvement for no one. Competitive convergence—the more benchmarking companies do, the more they look alike. [Thus] the result is zero-sum competition, static or declining prices, and pressures on costs that inhibit long-term investment."

<sup>10</sup> Fine, Charles. Clockspeed, Perseus, 1998.

creates a new single demand profile that will have higher variability than it otherwise would were this component used for all products, not only for this particular one.

- Defining a given number of Stock-Keeping Units (SKUs). One of the drivers of total cost in end-to-end supply-chain operations is complexity, as Nahmias suggests. From a pure supply-chain perspective, these costs are to be minimized, thus overall complexity must be minimized. The marketing department, however, would not agree with this goal. Depending on their objectives, they may actually be willing to offer several versions of the product, configurable to all segments and tastes. There is no process that sheds light on how to determine the right number of SKUs to best meet both groups' goals.
- Measuring the product development process and the effective application of DFX guidelines. DFX guidelines can be used to measure the joint design-manufacture process. Doing so allows for the track of improvement efforts and facilitates accountability of the team(s).
- Discussing customer needs. Because there is no process that helps engineers and marketers trade off their goals, not only can they not agree on the right number of SKUs, they cannot objectively assess other tradeoffs. It is common in the electronics industry, for instance, to add more features to a product for the sake of technological showoff. This may bring unnecessary cost and delays to the product launch and, in the end, subtract to the value proposition of the product.
- Deciding which tasks to (in/out)source as a function of future competitive advantages. This argument is probably Fine's most powerful<sup>11</sup>: knowing what to outsource and what to keep in-house is key to a given company's survival. Not only because of the inherent "Intel inside" trap, as he calls it, but also because, in order to bring a given task in-house, a given company should develop the necessary capabilities by choosing the right projects.
- Matching the life cycle of components with that of products. In the electronics industry, not only do products have short life cycles, components do too. And, because component life cycles are usually longer or shorter than expected, and are

---

<sup>11</sup> Fine. Ibidem.

not aligned with product life cycles, ensuring component availability at the right price throughout the product lifecycle is a challenge.

- Maximize savings by negotiating outsourcing work and parts procurement more holistically. Companies make use of economies of scale to procure parts and work at the lowest possible prices. However, a recent project carried out by a small group in the industry<sup>12</sup> proved that (1) some of the Contract Manufacturers (CMs) are vertically integrated enough to provide more value than originally assessed; (2) when presented with future projects, from more than the own product line, they were willing to reduce their prices further; (3) involving them in early design decisions avoided unnecessary costs and waste of time.
- Effective engagement of different members of the supply chain. Similarly, a more active overall engagement of the stake holders from the beginning of the PDD process is necessary to compensate for the lack of vertical integration.

All these activities can impact safety stock levels, time to market, and other supply-chain performance measures typically ignored DfX<sup>13</sup> guidelines. In short, product development teams, as a whole, seldom understand the supply-chain performance consequences of their decisions in customer satisfaction, total product cost, inventory levels, and lead-time, for instance. Some research has touched several related topics (design for supply-chain management (DFSCM), 3-dimensional concurrent engineering (3DCE), design for postponement, and others), but is either problem-specific or abstract, but not both. A more thorough overview of some of these ideas can be found in Chapter 2

Therefore, there has been no published work trying to consolidate this knowledge into a comprehensive process or set of guidelines that addresses the range of challenges an organization must address when it tries to improve its innovation process from a supply-chain performance perspective. This project has thus focused on developing such overarching guidelines, objectives and tools.

---

<sup>12</sup> Communicated during an interview in one of the companies. Unable to obtain further reference.

<sup>13</sup> DfX: Design for “X”; in one instance, “X” is used to represent “everything” an organization wants to impact through design; other users of the term use “X” for “excellence”, suggesting that this term should be the overall eclectic objective of a product-oriented firm.

## **2 BENCHMARKING AND REVIEW OF SOME EXISTING LITERATURE AND METHODOLOGIES**

### **2.1 Chapter Introduction**

Design for Supply Chain has not been defined. At times, people really mean Supply-Chain Design; at times, Design for Supply-Chain Management seems an extension of Design for Assembly or Design for Logistics that has left Supply-Chain Strategy out; 3DCE seems too strategic and theoretical, while Design for Postponement seems too specific and isolated. QFD indicates how to take customers' needs into the PDD process and translate them into excellent product and manufacturing process specifications, but it does not suggest what needs should be taken into account, especially from an end-to-end, strategic-and-tactical supply-chain perspective. This project has now looked at these isolated answers and put them all inside one framework that is applicable in any industry. Design for Supply Chain can now be defined then as the "Set of guidelines, objectives and tools that strengthen [a company's] innovation process from a Supply-Chain performance perspective in order to be able to gain or sustain competitive advantage."<sup>14</sup>

However, because DFSC actually draws all of its ideas from various sources of previous experiences and research work, it is worth looking at some of them in order to (1) understand them better and (2) understand how by themselves they are ineffective efforts from a holistic perspective.

### **2.2 Clockspeed and 3-Dimensional Concurrent Engineering (3DCE)**

As explained later (Chapter 4), a company can perform well to typical normal metrics and still fail to avoid strategic traps in the medium to longer run.

In order to understand the reach of Fine's ideas, the concept of "clockspeed" must be understood first by trying to answer the following questions:

- How fast are new products coming out? How fast are the Customers accepting new trends?

---

<sup>14</sup> Slightly modified version of the original definition presented in Chapter 1.

- How fast are business practices evolving?
- How fast is the process technology changing? How fast is parts and product technology changing?
- How fast is the competition forcing a company to redefine its strategies?

The perception that these processes and events take place at a different pace for a different company implies that these processes or industries or concepts have different clockspeeds. The next question may be, “Are these items going anywhere?” Figure 2 shows that these items can only move in one of two directions: either towards more integration or towards more modularization. Figure 2 depicts this phenomenon at an industry level, but technology, processes, products and organizations can all either integrate or modularize in time.

## The Double Helix

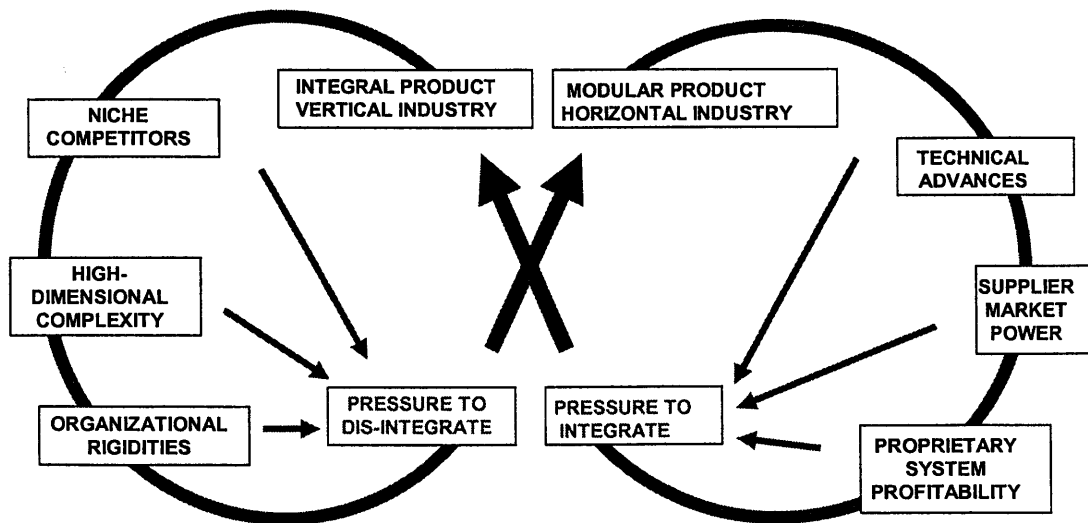


Figure 2 – The Double Helix.<sup>15</sup>

<sup>15</sup> Adapted from Fine, *ibidem*.



The following observations can be made:

- A given product, process, or organizational clockspeed may change.
- The integration/modularization Double Helix cycle may not be broken.
- However, the clockspeed of each product technology, process technology or business/organizational process that gives an organization a temporary competitive advantage can be measured.

## Dependence Dynamics

- **As we “*modularize*” or “*integrate*” our Product and Supply Chain architectures, we can potentially gain or lose capabilities.**

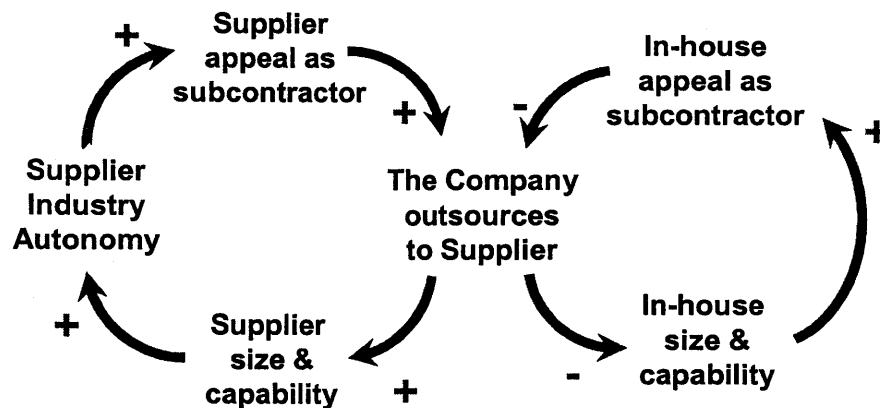


Figure 3 – Dependence Dynamics.<sup>16</sup>

And, at a given clockspeed...

- The market requirements that will rule in the near future can be identified; hence a company can design the right product at the right time.
- The new process technology that will be required to manufacture and assemble such new products can be determined.

<sup>16</sup> Adapted from Fine, *ibidem*.

## Vertical Industry Structure with Integral Product Architecture

Computer Industry Structure, 1975-85

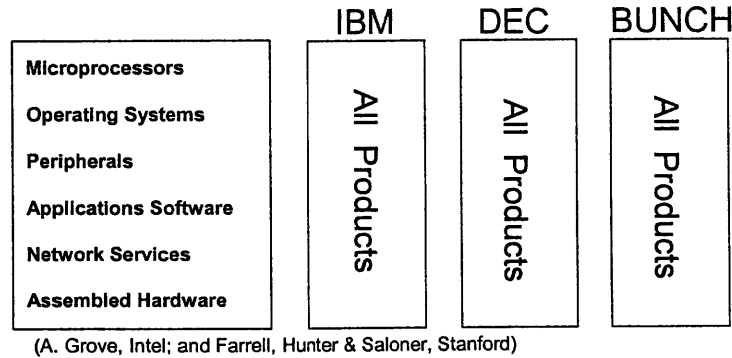


Figure 4 – From integral...

## Horizontal Industry Structure with Modular Product Architecture

Computer Industry Structure, 1985-95

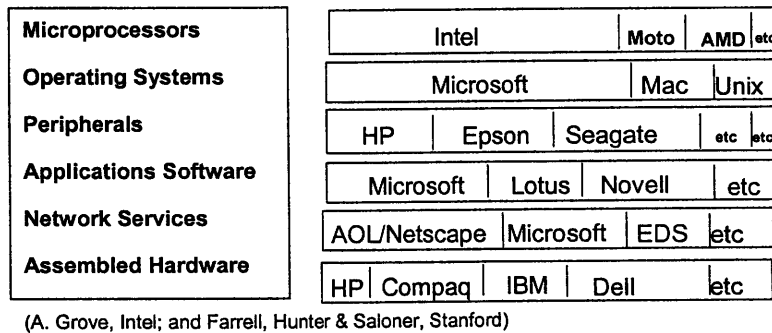


Figure 5 - ...to modular.

- The new supply-chain architecture that leads an organization to acquire a new temporary competence can be designed, while minimizing the risk of losing bargaining power.

Usually, when a product becomes modular, the supply base (and hence the industry) tends to become modular as well. (See Figures 4 and 5)

Design engineers already look at their supply base when they design products, and if concurrent engineering guidelines already require companies to design products and processes concurrently, it is only natural then to design product, process and supply chain in parallel. That is the concept of 3DCE. (See Figures 6 and 7)

## 3-D Concurrent Engineering

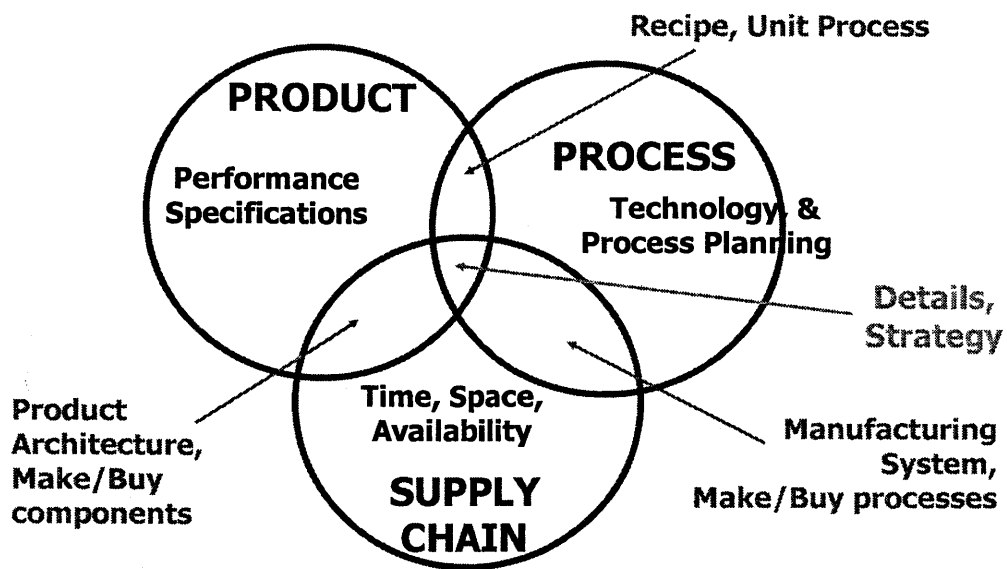


Figure 6 – The elements of 3DCE.<sup>17</sup>

Finally, Fine suggests a process to effectively utilize Clockspeed in strategy:

1. Benchmark fast clockspeed industries.
2. Map the organization's supply chain: Organizational Value Chain, Technology Value Chain, Competence Chain
3. Perform Dynamic Chain Analysis at each node of each chain map.

---

<sup>17</sup> Adapted from Fine. Ibidem.

4. Identify windows of opportunity.
5. Exploit competency development dynamics with 3DCE.

However, 3DCE and Clockspeed Analysis are not enough to build a solid, comprehensive framework to holistically marry PDD and SCM. Where 3DCE and Clockspeed are very strategic, the work done at Hewlett Packard (HP) to address practical problems of SCM becomes useful.

### 3-D Concurrent Engineering

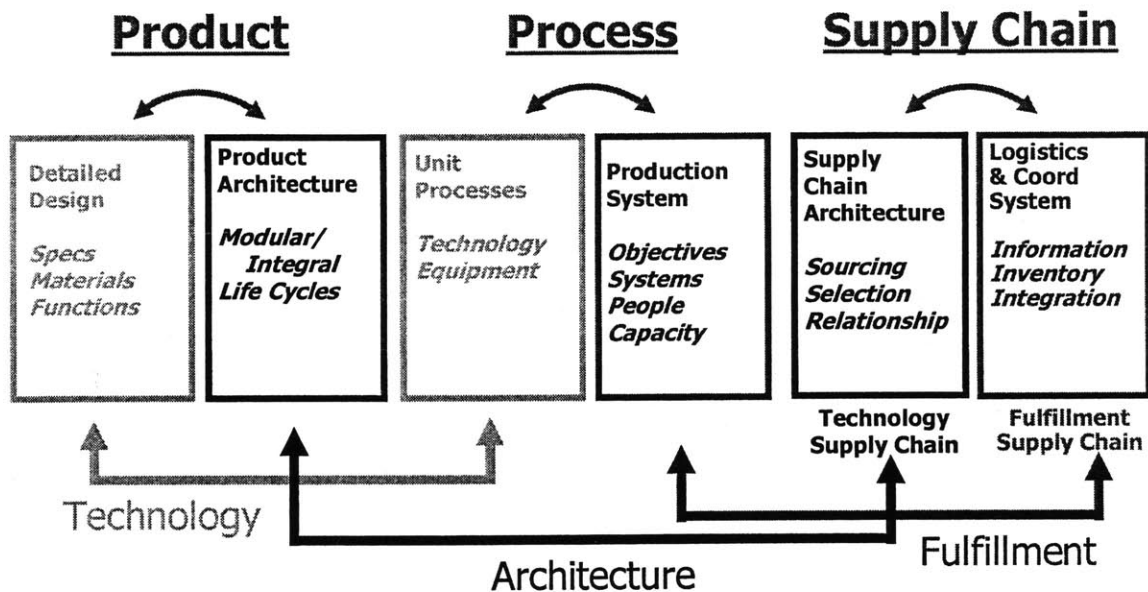


Figure 7 – The elements of 3DCE and the common threads.<sup>18</sup>

#### 2.3 Work Done at or in Collaboration with Hewlett-Packard

Several authors (e.g. Ulrich and Eppinger<sup>19</sup>, Fine<sup>20</sup>, Simchi-Levi<sup>21</sup>) quote the case of HP's deskjet printers as one in which the design of the product was modified to impact

<sup>18</sup> Adapted from Fine. Ibidem.

<sup>19</sup> Ulrich, Karl T. & Steven D. Eppinger. Ibidem.

<sup>20</sup> Fine, ibidem.

supply-chain performance. This case is used to present two of the issues discussed here: postponement (delayed differentiation) and universalization. The main benefit of these techniques is smaller total safety stocks through less demand variability.

This is one among many practical cases that HP's Strategic Planning and Management (SPAM) group has addressed for more than ten years. In another paper<sup>22</sup>, Cargille and Bliss talk about "rough-cut" methods to estimate the benefits of early involvement of the supply-chain function in product development in SKU reduction, tradeoffs of material costs vs. lead-time, and the value of increased delivery frequency.

However, although this paper clearly states that "supply-chain analysis can play a critical role in the three key phases of product development—investigation, design, and manufacturing or rollout," Lee and Sasser<sup>23</sup> christen the whole array of HP's techniques DFSCM or Design for Supply-Chain Management, name which suggests that HP's perspective on these problems is of a rather operational nature. Furthermore, during an interview with two members of HP's SPAM group, it became clear that they were not formulating an all-encompassing theoretical framework for these kinds of problems.

This observation suggests that, maybe, if there is DFSCM that addresses operational issues, there must also be Design for Supply-Chain Strategy (DFSCS) that addresses strategic issues. The following definitions clarify the differences:

- DFSCM, Design for Supply-Chain Mgmt, is a set of goals, tools, and guidelines that takes care of day-to-day business to optimize supply-chain performance under the current market conditions.
- DFSCS, Design for Supply Chain Strategy, ensures an organization does not lose sight of its present and would-be temporary advantages.

---

<sup>21</sup> Simchi-Levi, David et al, Designing and Managing the Supply Chain, McGraw-Hill, 2000.

<sup>22</sup> Cargille, Brian & Robert Bliss. "How Supply Chain Analysis Enhances Product Design." Supply Chain Management Review, Sep/Oct 2001, pp. 64-74.

<sup>23</sup> Lee, Hau & Marguerita M. Sasser. "Product Universality and Design for Supply Chain Management." Production Planning & Control, 1995, Vol. 6, No. 3, pp. 270-277.

These definitions and the previously shown DFSC definition gives the following, more complete definition of DFSC:

DFSC is the set of tools, guidelines, and objectives by which the Design function helps a company to achieve the strategic goal of continuously, efficiently and effectively meeting the demands of its customers by carefully crafting its Products, Processes and Supply Chain to gain temporary competitive advantage under each new set of market conditions.

In all, the work done by HP and Stanford helps organizations address DFSCM concerns while Clockspeed does so rather in the DFSCS field.

#### **2.4 Multi-Attribute Tradespace Exploration with Concurrent Engineering (MATE-CON)**

Among the tools analyzed for this research, MATE-CON is the one that had the largest impact, not only because of its demonstrated effectiveness in some of MIT research (Diller<sup>24</sup>, Ross<sup>25</sup>, and Stagney<sup>26</sup>) but because it is an answer to the question of how 3DCE can be implemented in reality. As explained in Chapter 3, MATE-CON is an excuse and a means to facilitate the discussion among three of the main functions that participate in PDD: Engineering, Marketing, and Manufacturing.

The Multi-Attribute Tradespace Exploration with Concurrent Engineering is a process that (1) tries to quantify the utility that customers seek to obtain from a product, (2) displays several versions of a system's architecture, and (3) allows for an objective discussion to take place.

---

<sup>24</sup> Diller, N. P. (2002). Utilizing Multiple Attribute Tradespace Exploration with Concurrent Design for Creating Aerospace Systems Requirements. Cambridge, MA. Massachusetts Institute of Technology. Aeronautics and Astronautics SM.

<sup>25</sup> Ross, A. M. (2003). Multi-Attribute Tradespace Exploration with Concurrent Design as a Value-centric Framework for Space System Architecture and Design. Cambridge, MA. Massachusetts Institute of Technology. Aeronautics and Astronautics; Technology & Policy Program Dual-SM.

<sup>26</sup> Stagney, D. B. (2003). The Integrated Concurrent Enterprise. Cambridge, MA. Massachusetts Institute of Technology. Aeronautics and Astronautics SM.

Diller suggests “it will be important to understand how the word utility is used. Fundamentally, it is simply a measure of goodness of a design. An ideal design is one, which creates the most utility. Typically the creation of this utility arises from the fulfillment of several different attributes. This thesis relies highly on the formalized multi-attribute utility theory, which mathematically aggregates those attributes into a single measure through a series of utility interviews. [...] Expense [...] is simply considered as the opposite of utility, drawing to some degree a contrast of utility being the good things that come from the system ( extraction of performance) and expense being the bad things that go into the system (consumption of resources). Expense follows the same definition as utility but is simply the inverse. Expense is a measure of pain. Instead of being a formal aggregate of all ‘good’ it is the aggregate of all ‘bad.’ This notion of utility is one of the most important intellectual points of MATE-CON. There are some good and some very, very poor methods of aggregating these preferences. Wise aggregation requires significant mathematical training with recognition of the importance of psychometrics, statistics, and decision theory. Great skepticism of such a process arises from the poor application of such aggregation techniques, and therefore one must be very clear about the validity of a particular approach.”

The major steps of MATE-CON are the following:

1. Identify (up to seven) attributes that the customer cares about.
2. Define their utility profile.
3. Prioritize them.
4. Compute total utility.
5. Perform several iterations of system-level design in which several utility-cost pairs are produced and plot them.
6. Discuss (in the context of a cross-functional team) the tradeoffs of each design version (i.e., of each utility-cost pair) and identify the winner system architecture.

Some of the users of MATE-CON, however, report a few limitations:<sup>27</sup>

- It is difficult to limit the analysis to seven attributes<sup>28</sup>

---

<sup>27</sup> As conveyed a few times by Stagney, who attends MATE-CON users’ group meetings.

- The processes to define utility profiles and to prioritize the attributes are complex and thus difficult to follow.

Some of the observations made under this research:

- The current version of MATE-CON does not single out lead-time or any other time component from other attributes. MATE-CON has been mainly used in the satellite industry, so users believe that lead-times can be included as the attribute “schedule;” the specific tradeoffs between cost and lead-time are not addressed.
- MATE-CON users thus far have seemed knowledgeable of the specific engineering variables required to measure their attributes. In a different industry, however, the customers may be the actual consumers, who may not be as knowledgeable, so they may express their desired attributes in subjective statements. The MATE-CON process does not explore this possibility and therefore does not offer a “translation” method<sup>29</sup>.
- The way in which attributes are analyzed may be excessive in other industries where they do not represent complex variables. In other words, the resolution of this attribute analysis may be too high for some simpler attributes.

Overall, MATE-CON makes a perfect tool for objective discussion in a cross-functional environment. MATE-CON itself does not suggest what attributes should be included in the discussion. It should, however, address the need for a third axis to plot time values independently.

## **2.5 Quality Function Deployment (QFD)**

Quality Function Deployment is one of the methods used by the Japanese in the field of product development as part of the larger philosophy of Total Quality Management. It

---

<sup>28</sup> The proponents of MATE-CON base their decision to limit this number on empirical observations that suggests that, at one time, human beings cannot compare more than seven things.

<sup>29</sup> Strictly speaking, there are a few techniques to quantify subjective variables, but the MATE-CON process does not seem to make use of them. As of the release date of this thesis, Guerrero and Stagny were working on a draft paper to discuss the incorporation of these techniques.



is a systematic way to identify customer needs accurately in order to satisfy them effectively. The process can be summarized as follows:

1. Identify and prioritize corporate or project goals.
2. Identify customer segments, and estimate their weight relative to each other as a function of the corporate or project goals.
3. Select a few “gemba;”<sup>30</sup> a gemba is a set of who-what-where-when-why-how conditions under which the product or service in question is used.
4. Perform gemba visits (i.e. field observations and/or interviews) to gather “the voice of the customer.”
5. Translate customer statements into “demanded quality” statements.
6. Have customers prioritize these.
7. Identify the variables that engineers manipulate to provide value to customers.
8. Correlate demanded quality with engineering variables to identify their relative weight. This is done in a matrix that is usually known as “the House of Quality.”
9. Through successive matrices, the relevant Functions, Reliability Issues, and Technology Components are identified.
10. Later steps introduce costs, safety, environmental and other factors.
11. Some of these elements in turn feed into FMEA (Failure-Mode-and-Effect Analysis) or other processes to translate product requirements into manufacturing process requirements.

Given the training of the author as QFD Black Belt<sup>31</sup> and given the research done for this project, the following observations can be made:

- By delaying the inclusion of cost and other data, QFD seemingly fails to acknowledge that there are other “customers” of the product development process whose requirements are as important as those of the consumers.
- QFD does acknowledge these other types of data, but does not offer a specific way to introduce them to the process or, more importantly, to have the cross-functional team trade them off to reach the best possible solution.

---

<sup>30</sup> Pronounced “GHEMM-bah,” it is a Japanese word that literally means “actual place” and, practically, the workplace.

<sup>31</sup> Course material prepared by Mazur, Glenn, for “Quality Function Deployment” course, 2000.

- Similar to other methodologies and cases, QFD does not seem to say anything about the strategic consequences of outsourcing components. These strategic considerations may go into the process, but are not required to.

In short, QFD is a very good approach to PDD, but does not make any statements about supply-chain-specific considerations. However, QFD could in fact be the foundation on which the 14 recommendations overlay.

## **2.6 Summary**

As seen thus far, the HP cases and Fine's work complement each other, for the one addresses operational issues of DFSC while the other addresses strategic issues of 3DCE. When these considerations are traded off in an environment like MATE-CON, and when cross-functionality and effective need identification can take place like in QFD, there is a solid platform to implement the DFSC recommendations that give any company a continuous competitive advantage. Modifying Fine's words a bit, "[Design] is the ultimate core competency: competency of passing judgement on all other competencies."

### 3 RECOMMENDATIONS

#### 3.1 Chapter Introduction - The 14 Recommendations

The questions around how to improve the industry's innovation process from a supply-chain performance perspective span a broad set of operations and fields of knowledge. For this reason, this research draws information from previous work done (as reviewed in Chapter 2) in these different operations. The following 14 recommendations provide answers to these questions:

1. Perform product/process/supply-chain design before every major product launch. Include Technology Roadmap analysis and competitor and supplier assessments (in other words, Clockspeed Analysis as defined by Fine). **IV-1a**<sup>32</sup>
2. Enhance supply-chain collaboration with all stakeholders continually. **IV-2**
3. Determine optimal variety of SKUs. **III-1**
4. Assess total supply-chain costs and lead-time. **II-1**
5. Ensure product-component life cycle match. **II-2**
6. Implement Cost Avoidance. **I-1**
7. Apply Part & Enclosure Reuse and Commonality (including Universalization) principles when selecting key and unique components. **I-2a**
8. Select best design through a Utility vs. Costs vs. Lead-Time or Time to Market (TTM) analysis at a formal cross-functional design review. **I-3a**
9. Apply DFA, DFM, Design for Testing (DFT) + Design for Returns, Design for Recycling (DFR<sup>2</sup>)<sup>33</sup> + Design for the Environment (DFE) guidelines earlier. **I-4**
10. Begin Design for Logistics (DFL) analysis earlier. **I-5**
11. Expand the application of Postponement. **I-6**
12. Apply Part Reuse and Commonality principles when selecting Common Components. **I-2b**
13. Perform Design Assessment at the end of each product launch as per (8). **I-3b**

---

<sup>32</sup> An explanation of the use for this Roman numeration will be given in Chapter 4.

<sup>33</sup> The term "DFR<sup>2</sup>" is being used to avoid using a double "DFR."

14. Perform Capabilities Assessment at the end of each product launch towards the goals set in (1). **IV-1b**

The following diagram (Figure 8) depicts where in the PDD process these recommendations could be inserted.

## The 14 DFSC Recommendations...

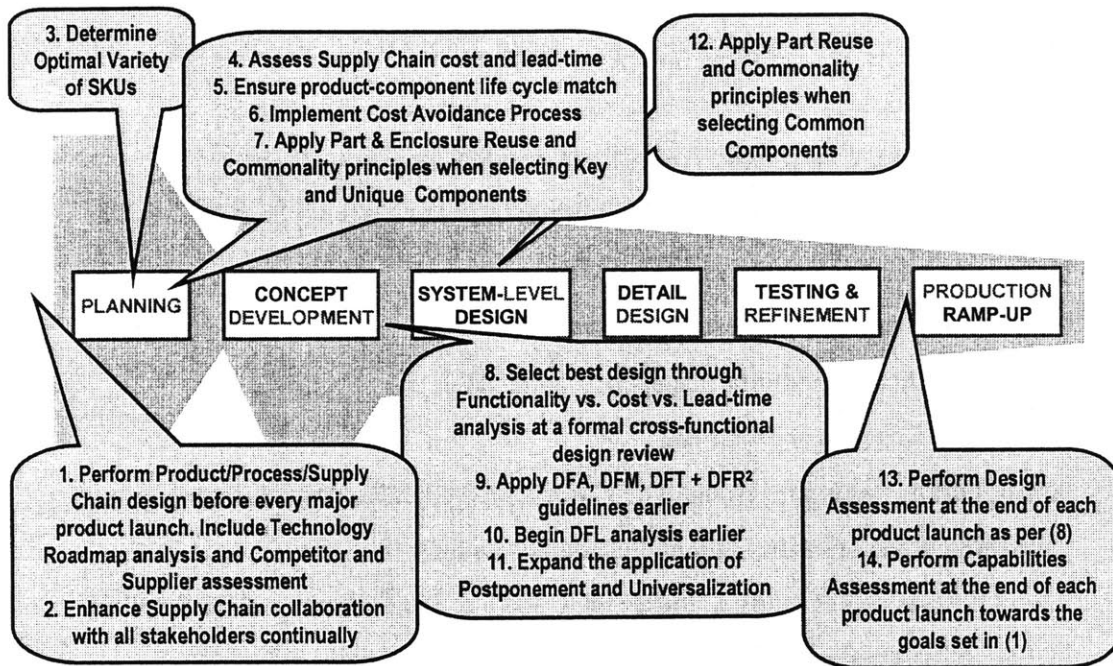


Figure 8 – The 14 DFSC Recommendations in reference to the generic PDD process from Ulrich and Eppinger.

Each recommendation is covered below in full. An explanation is provided, followed by a description of the observed current state in the industry, the proposed desired state, and the required next steps to reach the desired state.

## “The Black Box”

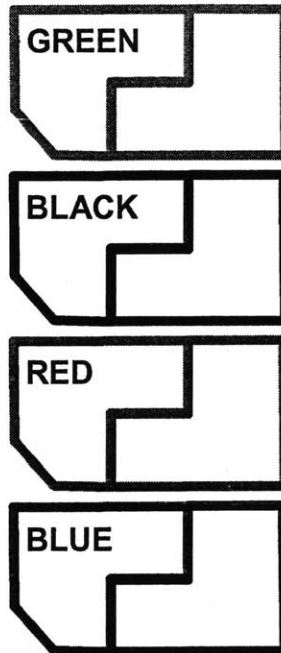


Figure 9 – The Black Box. A fictitious product used to exemplify a few recommendations.

For some recommendations, an example based on an imaginary product, “The Black Box” (Figure 9), is presented. The Black Box comes in four versions: green, red, blue and black. It is made of two components only, which are similar but not identical. The examples show how the recommendation in question would affect the design or manufacture of the Black Box in order to make it clearer.

### **3.2 No. 1, 14 – Perform Product/Process/Supply-Chain Design Before Every Major Product Launch. Include Technology Roadmap Analysis and Competitor & Supplier Assessment (IV-1a, b)**

Fine suggests that the design of the supply chain is as important as the design of the product or process. Just as the term “concurrent engineering” was coined to mean the simultaneous design of product and process, Fine uses the term “3-dimensional

concurrent engineering,” or 3DCE, to mean the simultaneous design of product, process, and supply chain. He then goes a step further to describe what he calls “Clockspeed Analysis,” which provides a framework to develop 3DCE thinking and processes.<sup>34</sup>

## Growth Differential among IBM, Intel, and Microsoft

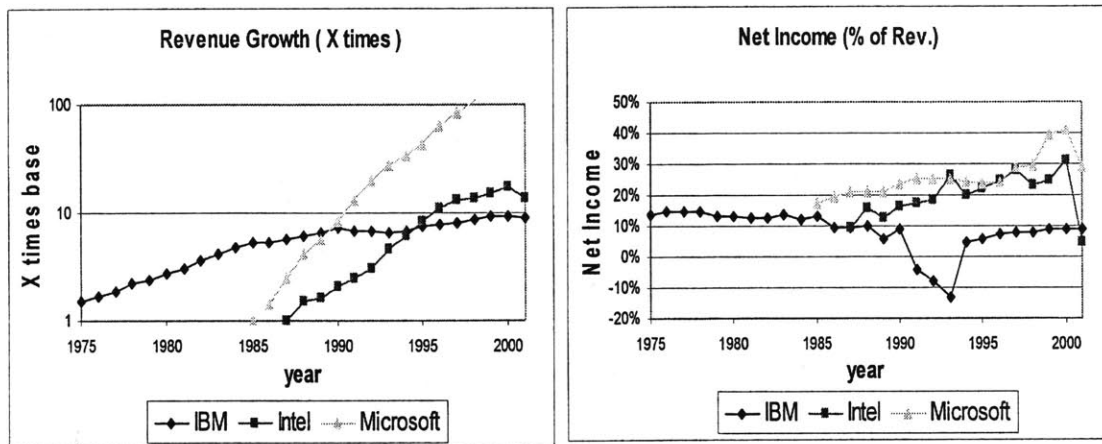


Figure 10 – Growth differential among IBM, Intel and Microsoft in dollars.

One of the fundamental breakthrough observations of Fine, and the purpose for which this Clockspeed Analysis was developed, is that companies may be incurring a risk when they outsource blindly to reduce costs. The typical example is the “Intel inside” case, as he calls it, in which IBM lost control of the supply chain to its subcontractors by outsourcing not only for capacity but also for knowledge, assuming that their products would never be as important as the computer itself. Thus, Fine states that “The Make/Buy

<sup>34</sup> A more detailed explanation of Fine’s work (3DCE, Clockspeed Analysis, etc.), as described in his book, is given in Chapter 6.

decision is the ultimate competency.” Intel and Microsoft grew several times more than IBM since then, as shown in Figure 10.<sup>35</sup>

The industry already makes use of “technology roadmaps” as guidelines for their manufacturing groups to translate the engineering specifications into manufacturable, assemblable, and outsourceable products (a step towards 3DCE). As Ulrich and Eppinger suggest, “technology roadmapping can serve as a planning tool to create a joint strategy between technology development and product development.”<sup>36</sup>

A typical technology roadmapping process may look like this:

- a) Marketing and engineering look at the market trends and plot their product segment maps, which show the time of market introduction of future products.
- b) Manufacturing translates these maps into specifications as to what component, product, and (manufacturing and assembly) process technologies are required to develop those new products. This group then produces the technology roadmaps that outline this course of action.
- c) Manufacturing then identifies suppliers that are aligned with the desired technology roadmap and communicate the future requirements to suppliers.

A technology roadmapping process like this, however, gives no indication of any likely risk of losing supply-chain control to a supplier or CM. That is, in order to avoid an “Intel inside” problem, it should also flag the risk of outsourcing certain technologies in the future. This can be done by answering the question “Is this new technology likely to become more important to the customer so that we should insource it?” every time the technology roadmapping process is applied. In the affirmative, the outsourced components should be discontinued and the affected engineering team should take the necessary steps to learn to design the soon-to-be in-house components.

---

<sup>35</sup> IBM outsourced the operating system to Microsoft and declined shares of the new industry; MS has grown at least 180 times and IBM hardly 3 times since then. Intel became the main supplier of CPUs and has grown 14 times since then.

<sup>36</sup> Ulrich and Eppinger. *Ibidem*, pp. 44-45.

### **Observed Current State**

- Current technology roadmapping processes collect information around pressing technology issues, industry-wide roadmaps, individual technology roadmaps, industry roadmaps, competitor roadmaps, etc. Customers of these processes are individual-technology owners and managers that drive investments and projects.
- These processes do look at future product technologies and supply chain architectures based on the current product segment maps. CM capability to meet the technology and quality requirements is assessed

### **Desired State**

- The technology roadmapping process includes an analysis of integration (or modularization) of each technology to enable the anticipation of competitors, suppliers or customers strengthening relative to a given company, which should then in/outsource for knowledge or capacity accordingly.
- Directives coming from these decisions feed discussions before a new platform launch and are reflected in the marketing-requirements document (MRD)

### **Next Steps – The Specific Recommendation**

1. Assemble a cross-functional team.
2. Following currently-identified supply-chain configurations perform initial Clockspeed Analysis – Technology, Organization, and Capability roadmaps.
3. Identify market, competitor, supplier and technology conditions 2-3 years ahead and define goals (Double Helix analysis).
4. Define continual 3DCE process independent or not from current technology roadmapping process.



### Example

Figure 11 suggests two possible fates for the technology embedded in The Black Box. Today, the requirements for The Black Box are met by the current components. Depending on the Double Helix dynamics, the functions of both components may become available in the future in one component (integration), or in three (modularization).

## IV-1. Perform Product, Process, Supply Chain design for proper in/outsourcing

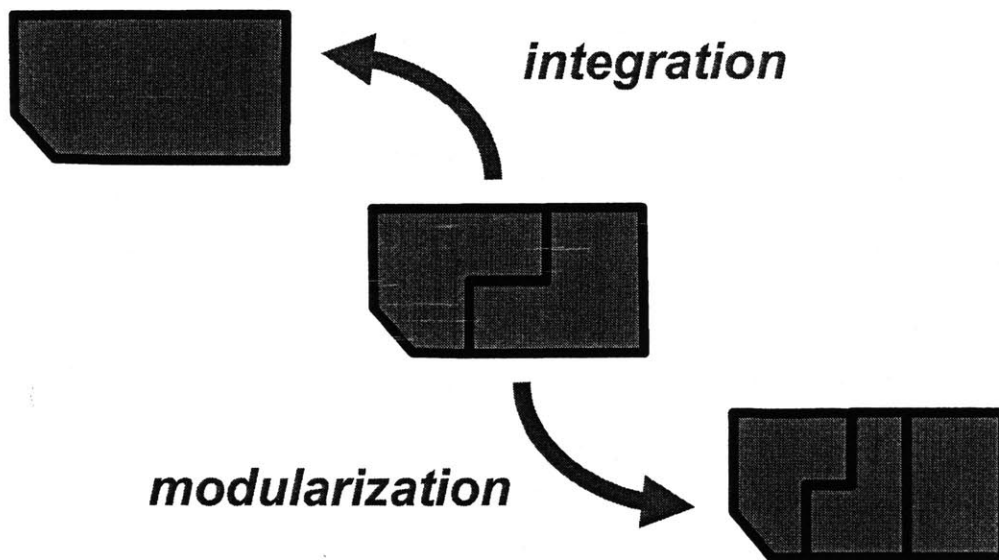


Figure 11 – Example of Recommendation 1. If the anticipated component is perceived to become more valuable for the customer than today’s components, the right decision to insource it can be made.

In order to fall in the “Intel inside” trap, three things need to happen:

- a) For some reason, the customer or end consumer finds that some functions of the product are the most valuable.
- b) The design team in question does not know how to design one of the new components that incorporates these customer-valued functions

- c) The team decides to have (or keep) the new component outsourced.

### **3.3 No. 2 – Enhance Supply-Chain Collaboration With All Stakeholders Continually (IV-2)**

One of the consequences of extensive outsourcing is the realization of a new need: OEMs<sup>37</sup> should trust their CMs and suppliers beyond the usual legal terms. Many an example (Toyota and Chrysler, to name a few<sup>38, 39</sup>) have proved that extended collaboration between supply-chain players. When these players acknowledge that they are in for a long-term partnership; in particular, when a powerful OEM realizes that it cannot squeeze its suppliers to get unilateral benefits, the relationship not only turns profitable but it becomes sustainable and multiplicative of their skills. Some of the observations done by Womack et al and by Dyer can be summarized as follows:

- Toyota and Chrysler have recognized the supplier's right to profit; they have committed to share good and bad times.
- Suppliers are involved early in the process through open contracts with risk-sharing clauses.
- Before work is awarded, competing suppliers have access to draft designs at system level, in order to allow for their input.
- The expression “market price minus, not supplier cost plus” as reported by Womack et al<sup>40</sup> is explained by the joint effort both the OEM and the supplier make to reduce cost. In other words, it is assumed that the price is given, they work backwards to figure out the cost to meet, and then they collaborate to succeed in the improvement effort.

---

<sup>37</sup> Original Equipment Manufacturers.

<sup>38</sup> Dyer, Jeffrey H. Collaborative Advantage: Winning through Extended Enterprise Supplier Networks. Oxford University Press, 2000.

<sup>39</sup> Womack, James et al, The Machine That Changed the World. Harper Perennial, 1990.

<sup>40</sup> Womack et al. Ibidem.

## **Observed Current State**

- CMs are first engaged in PDD at random. More suppliers and CMs are willing to enter earlier negotiations and participate more in PDD.
- Opportunities to avoid cost are discovered later in the PDD process, once resources have already been committed.
- The industry ignores the actual cost of manufacturing flexibility and the amount of flexibility it requires from suppliers.

## **Desired State**

- Following Recommendation 1, the industry should join talks with its strategic partners (suppliers and customers) often to guarantee the creation of value for all. These directives may need to be reflected in the cross-functional product team.
- A different contractual structure can enable better collaboration.

## **Next Steps – The Specific Recommendation**

1. Assemble a cross-functional team.
2. Benchmark Toyota, Chrysler (others?) to device new contractual agreements.
3. Define additional steps in the procurement and supplier qualification processes, and others, as appropriate.

### **3.4 No. 3 – Determine Optimal Variety of SKUs (III-1)**

The industry produces thousands of SKUs due mainly to customers' demands. However, not creating a large number of SKUs in the first place is what matters.

There are various ways to calculate the cost that variety adds to the design and manufacturing processes.<sup>41</sup> This is apparently good for design and manufacturing

---

<sup>41</sup> Martin, Mark V. & Kosuke Ishii. "Design for Variety: Development of Complexity Indices and Design Charts." Proceedings of DETC '97, 1997 ASME Design Engineering Technical Conferences, Sep. 14-17, 1997, Sacramento, CA.

engineers, for they are the ones who seem to suffer the most when product variety increases. However, there are few objective methods that assess the marketing argument: customers want variety and the industry must cater to their very last and unique needs by producing several SKUs.

### **Observed Current State**

- Striking the right balance between breadth of product offering and cost constraints is a challenge for the industry.
- Cargille and Bliss at HP describe the use of a quick safety-stock reduction method to persuade Marketing to reduce the number of SKUs at each product launch.<sup>42</sup>

### **Desired State**

- Marketing better determines the right number of SKUs during Product Definition with two goals in mind: (1) minimum number of SKUs, in order to minimize final goods safety stock inventory; (2) maximum market power of remaining SKUs, in order to keep meeting customer needs. This analysis should appear in the MRD.
- Goal 1: It can be achieved with the quick safety-stock reduction method<sup>43</sup>
- Goal 2: Further research on the Herfindahl-Hirschman Index (HHI)<sup>44</sup> should be carried out in order to determine its applicability.

### **Next Steps – The Specific Recommendation**

1. Identify the right cross-functional team.

---

<sup>42</sup> Cargille and Bliss. Ibidem.

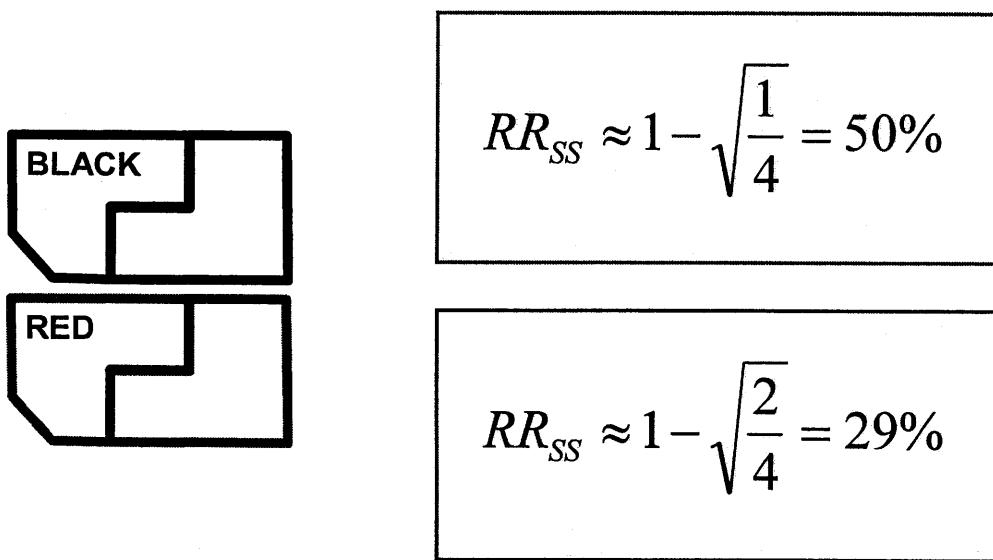
<sup>43</sup> Cargille and Bliss. Ibidem.

<sup>44</sup> <http://www.usdoj.gov/atr/public/testimony/hhi.htm>, accessed last on March 3, 2003. “‘HHI’ means the Herfindahl-Hirschman Index, a commonly accepted measure of market concentration. It is calculated by squaring the market share of each firm competing in the market and then summing the resulting numbers. For example, for a market consisting of four firms with shares of thirty, thirty, twenty and twenty percent, the HHI is 2600 (30<sup>2</sup> + 30<sup>2</sup> + 20<sup>2</sup> + 20<sup>2</sup> = 2600). The HHI takes into account the relative size and distribution of the firms in a market and approaches zero when a market consists of a large number of firms of relatively equal size. The HHI increases both as the number of firms in the market decreases and as the disparity in size between those firms increases.”

2. Research literature and benchmark companies to identify methods that use HHI to determine the optimal number of SKUs.
3. Define preliminary process(es) around HHI and HP's method; scope rules or tools that challenge the number of SKUs from the beginning of the PDD process.
4. Study a few products to assess the likelihood of extra profit.
5. Modify the marketing process to include these new steps.

**Example**

### III-1. Determine Optimal Variety of SKUs



*assuming same demand, service level, lead time*

Figure 12 – The quick method, as described by Cargille and Bliss: given the assumptions, reducing the number of SKUs from four to one may bring 50% reduction in safety stock; from two to one, there is still a 29% reduction in safety stock.

Besides a reduction in costs due to complexity, reducing SKUs brings immediate savings in safety stock volume. In the Black Box example, it is assumed that one redesigned SKU meets the requirements for the original four. The total demand for this

one SKU is therefore the same, which does not change the total required inventory volume. However, because the demand profiles of the individual SKUs carry more variability as a whole than the single redesigned SKU, the total safety-stock volume of the original four is less than the safety-stock volume of one. (See Figure 12)

### **3.5 No. 4 – Assess Total Supply-Chain Costs and Lead-Times (II-1)**

It is well known that a strong reason behind the large amount of outsourcing and the flow of manufacturing activities to other countries is cost. The economic argument is that of comparative advantage: labor in some developing countries has proved to be cheaper while being (reasonably) skillful and, since corporations seek to improve the economics of their operations, factories have closed all over North America, Western Europe, and recently, Japan in the pursuit of labor in the developing world.

Having displaced manufacturing overseas in an unplanned manner, however, has generated unforeseen costs for the industry and society in general. Recently, as the economic slowdown turned their attention to process improvement and cost cutting, in some cases it was found that product was moved from one location to the next and to the next, only to go back to the original location or to end at a customer's door in another region way beyond the promised delivery date.

#### **Observed Current State**

- In the planning phase of PDD, cost figures usually ignore supply-chain costs that, when incurred, may inadvertently tilt Gross Margin negatively.
- Product placement decisions are usually made by the manufacturing groups shortly before production ramp-up, affecting the final product cost structure.

#### **Desired State**

- The MRD includes an analysis of the product-specific supply-chain configuration.

- This analysis includes an assessment of tradeoffs among customer utility, costs, and lead-time and time to market.

### **Next Steps – The Specific Recommendation**

1. Develop a process that assesses total supply-chain costs and lead-times.
2. Assess the likelihood of using MATE-CON for tradeoff analysis in this process.

### **3.6 No. 5 – Ensure Product-Component Life-Cycle Match (II-2)**

In the electronics industry, not only do products have short life cycles, components do too. Because component life cycles are usually longer or shorter than expected, and are not aligned with product life cycles, ensuring component availability at the right price throughout the product lifecycle is a challenge.

Fine explains this as a result of the different clockspeed of the technologies represented by the individual components and of the overall clockspeed of the product. Since individual companies are making decisions that only optimize their condition, there is no concerted effort—or motivation—to manage this difference in goals. The industry, however, does suffer from this condition. In one case, up to fifteen percent of component inventory was accumulated only to hedge the risk of the component going offline.

#### **Observed Current State**

- Companies do not have a formal process to estimate End of Life (EOL).
- For various reasons, suppliers prefer not to give advanced price information; if they do, this information is most likely inaccurate.

#### **Desired State**

- The component selection process includes an analysis of the right match between product life cycle and the life cycle of (at least) key components; i.e. ensuring

component availability, in the right volumes, at the right prices, for each product life-cycle stage: Introduction, Maturity, EOL.

- This process is done iteratively and in parallel with the supply-chain cost-and-lead-time analysis (Recommendation 4).
- Improved, earlier negotiations with suppliers guarantee component availability.

### **Next Steps – The Specific Recommendation**

1. Assemble a cross-functional team that benchmarks industry and research, and scopes this process-developing project.
2. Define a draft process (equations or visual method) that enables this type of life-cycle analysis; explore synergy with cost-avoidance processes.
3. Assess the effectiveness of this process and produce the final version.

Although there may be several ways to address this challenge, depending largely on the goals and scope of the intended process, one simple way to do this analysis is to provide visual representation of the main unknowns: component price profile (price at  $t_0$ , average price in Sustaining, and final price); product price profile; production volume profile (for both, the product and the relevant components); and variability (confidence intervals for each price and volume figure). Figure 13 explains this better.

### **3.7 No. 6 – Implement Cost Avoidance (I-1)**

It is expected that procurement organizations in any industry are continually trying to maximize savings by negotiating outsourcing work and parts procurement more holistically. However, a study done in the industry has proved that (1) some of the CMs are sufficiently vertically integrated to provide more value than originally assessed; (2) when presented with future projects, from more than one product lines, they are willing to reduce their prices further; (3) involving them in early design decisions avoids unnecessary costs and waste of time.



## II-2. Product-Component Life-Cycle Match

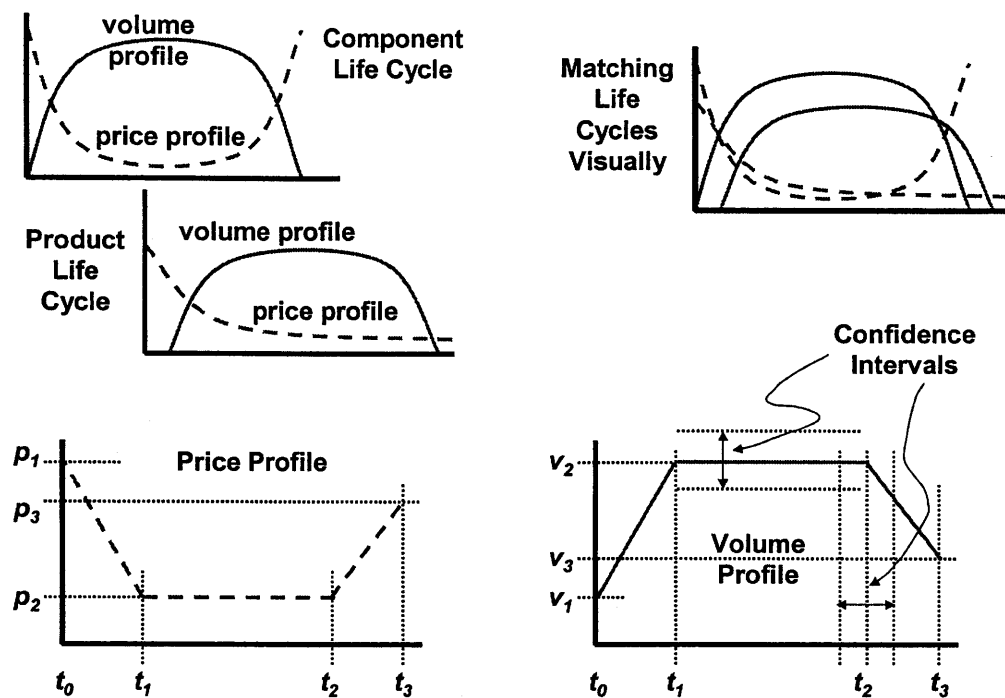


Figure 13 – One of many possible ways to assess the product-component life-cycle match.

### Observed Current State

- Value engineering efforts in any company usually uncover opportunities for product cost reduction. This usually happens when the product has reached its maturity, which makes any efforts to implement the recommendations very costly.
- In a particular case, a design team identified negotiation points with suppliers that have saved its company unnecessary costs before product requirements are set. This team has then created a draft version of this cost-avoidance process.

### Desired State

- “Best in class” companies focus improvement efforts earlier on the product development process. (See Figure 14)

- Opportunities: Pre-design negotiation, design architecture selection, operations, accessory kit, layout optimization of Printed Circuit Board (PCB), freight.
- This process is done iteratively and in parallel with the supply-chain cost-and-lead-time analysis (Recommendation 4).

## Fewer Design Changes

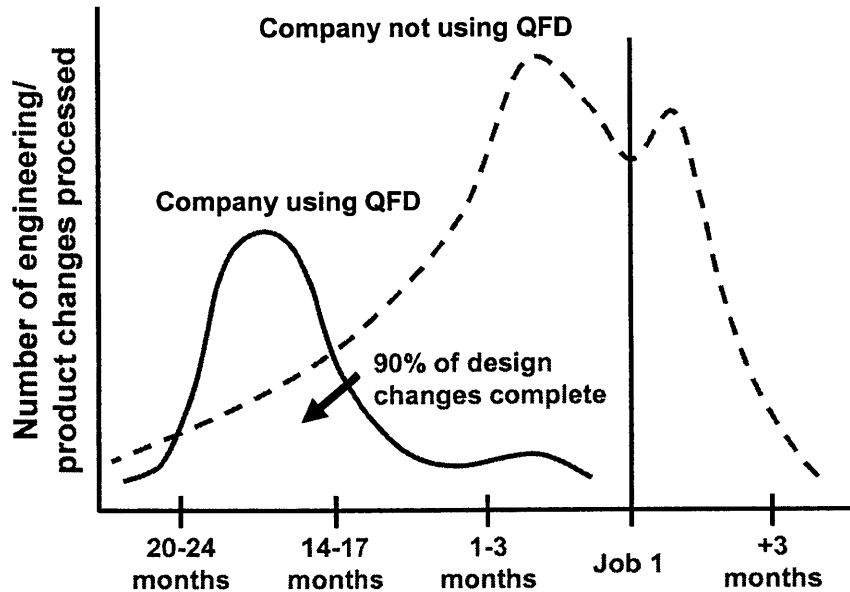


Figure 14 – Any organization that applies some form of cross-functional integrated PDD process can realize the following benefits: “reduced pre-launch changes from changing customer needs and competitive pressures; reduced pre-launch changes resulting from transition from prototype to production; reduced post-launch changes due to missed requirements, quality problems.”<sup>45</sup>

### Next Steps – The Specific Recommendation

1. Coordinate with the design team that created the original process.
2. Identify parts of this process that can be generalized for the industry; adapt the rest to be equally applicable.

<sup>45</sup> Mazur, Glenn. Material for “Quality Function Deployment” course, 2000. Plot adapted from L. P. Sullivan, “Quality Function Deployment.” Quality Progress, June 1986.

3. Determine repository document for this process (PDD Engineering Manual, Quality Procedures, Procurement Uniform Operating Procedures, etc.)

### **3.8 No. 7, 12 – Apply Part & Enclosure Reuse and Commonality (Including Universalization) Principles When Selecting Components (I-2)<sup>46</sup>**

In this industry, design engineers lack processes to select components in a way that (1) minimizes the total number of components per product and across product lines; that (2) minimizes the number of versions of components; and that (3) modifies the system design to accommodate common components and enclosures. Most design engineers do have access to component databases but, doing an individual search is very time-consuming and its effectiveness depends largely on the experience of the engineer.

#### **Observed Current State**

- Most design engineers are aware of the benefits of part reuse and commonality, and would like to use them thoroughly, but lack the processes to do so.
- Key, unique components are often selected before product requirements are approved; the information required is not easily available at this stage.

#### **Desired state**

- When selecting all components, part reuse and commonality are maximized.
- Engineering and Manufacturing collaborate virtually for component.
- Improvement in the application of these principles is measured.

#### **Next steps – the specific recommendation**

1. Assemble a cross-functional team.

---

<sup>46</sup> Part Reuse, Commonality: The fewer the components, the smaller the investment in total component safety stock, the higher the quality assurance, the better the tracking of technology. Universalization: One version of commonality, the opposite of component customization for regional use. Universalization benefits from aggregate demand risk pooling.

2. Consult best practices and academic research to identify practical processes and guidelines that can be implemented across the industry.
3. Create a process to be included in the IT tools that engineers use; important tasks are: keeping statistics of part reuse and estimating safety stock savings.

### Example

## I-2. Apply ... Commonality ...with a bonus

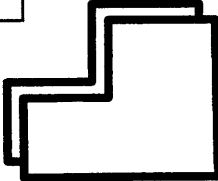
$$RR_{SS} \approx 1 - \sqrt{\frac{1}{2}} = 29\%$$


Figure 15 – One immediate benefit of commonality.

One of the obvious benefits of the application of commonality and part reuse is, as in the case of SKU reduction, the decrease in total safety stock volume. Figure 15 shows the estimated reduction in safety stock; this follows the logic that one component is found to be able to satisfy the requirements of two after redesign.

Also, measuring the effectiveness of commonality and part reuse brings more benefits. Table 1 shows some data for a few variables that a given HP team kept track of for a product launch. This example makes evident the improvement from a previous, similar model to the previous (reference) model to the current. Measuring these variables ensures

the commonality goals are met and guarantees that the PDD teams involved will be aware of the results of their effort. Metrics like these help focus the attention of the team on what is relevant for the organization, away from individual, group or department goals.

## HP 34401A multimeter DFM results

	<b>% Current</b>	<b>% Previous</b>	<b>% Previous Similar</b>
• <b>No. mechanical parts</b>	<b>30</b>	<b>100</b>	<b>190</b>
• <b>Final assembly part count</b>	<b>40</b>	<b>100</b>	<b>153</b>
• <b>Total parts</b>	<b>68</b>	<b>100</b>	<b>190</b>
• <b>Total part numbers</b>	<b>77</b>	<b>100</b>	<b>150</b>

Table 1 – Measuring improvement in commonality and part reuse.<sup>47</sup>

### 3.9 No. 8, 13 – Select Best Design Through a Utility vs. Costs vs. Lead-Time (or TTM) Analysis at a Formal Cross-Functional Design Review (I-3a, b)

As suggested by the previous example and by Recommendation 3 (variety of SKUs), having a cross-functional team is not enough guarantee a cross-functional process. There are three issues about cross-functionality that have not been met in most companies:

- The right time to join the team. The whole point about cross-functionality is to seize the knowledge of the different parties in order to (1) maximize the inclusion

<sup>47</sup> Adapted from Shina, Sammy G. Six Sigma for Electronics Design & Manufacturing, McGraw-Hill, 2002.

of relevant matters and thus (2) minimize the risk of encountering obstacles later in the process, and even after the process; this in turn can be translated into monetary and time savings. Therefore, when all the functions are not represented at the right time, this dual goal is not met. As portrayed by Figure 8, a PDD team that addresses most concerns upfront has fewer design changes overall and fewer—if any—changes after product launch. This can only happen if the team is truly cross-functional from the beginning—even if the presence of all functions is not apparently necessary—and this may include customers and suppliers.

- An appropriate tool for effective communication of perspectives and tradeoffs. Now, having all function representatives in one room does not guarantee that they will be able to sort out priorities in order to determine the right steps and tasks. It is obvious that communication will be difficult, and it is not at all outrageous to think that some will be willing to exert their influence or political power in order to tilt the balance their way. Since this may go against the interests of the organization or at least against the overarching project goals, it is important to have a method or a tool that makes the discussion more objective and the greater goal(s) apparent to everybody.

Common goals and metrics. When goals are set for the entire team, proper metrics can be put in place to ensure progress towards such goals. How the team measures to the metrics should be an important basis for incentives and accountability.

Furthermore, overarching goals and metrics can also be used to track PDD performance over time. Contrary to what many may believe, the HP example presented earlier proves that, although actually different from each other, new products offer opportunities to improve PDD skills. Therefore, tracking progress from project to project, and even from division to division can drive overall product-launching skill improvement.

### **Observed Current State**

- Product innovation is constrained by DfX, target costs, explicit customer needs, etc. Engineering, Marketing and Manufacturing have valid reasons to argue for or

against these constraints. However, discussions for resolving these differences are subject to people's biases (expertise, convictions, etc.).

- How different combinations of these constraints affect the final design selection is not quantified. Further, there is no comprehensive metric that measures an organization's design capability and allows for process improvement.

### **Desired State**

- New Product Introduction tradeoffs: among Utility, Product Launch Cost, and TTM; Sustaining tradeoffs: among Utility, Total Landed Product Cost, and Lead Time. These tradeoffs are scrutinized objectively by Engineering, Marketing, and Manufacturing with MATE-CON<sup>48</sup>—which constitutes a common language and a common metric—to improve TTC, TTM, TTQ, TTV<sup>49</sup> and overall supply-chain performance.
- The MRD should get the appropriate overarching targets: Utility, Costs, Lead Time, TTM, etc.
- A cross-functional team selects the best system-level design at a formal design review prior to committing major resources; later design efforts can focus on improving the performance of the design or reducing the lead-time without increasing the cost.

### **Next Steps – The Specific Recommendation**

1. Form a cross-functional team for scoping the reach of this recommendation.
2. Study the MATE-CON process in order to adapt it to the industry's circumstances.
3. Select and train a pilot group that can follow the process as a trial run.
4. Gather feedback on the pilot and prepare the definitive process, including the suggestions of Engineering, Manufacturing, and Marketing.

---

<sup>48</sup> The Multi-Attribute Tradespace Exploration with Concurrent Design tool measures Customer Utility and Costs of a given design (a third axis, Time, can be added for supply-chain relevance). In an iterative process, it is used to select the best system-level design; it has been developed and is being used at MIT to design commercial satellites. A more thorough description is provided in Chapter 5.

<sup>49</sup> Time to Cost, Time to Market, Time to Quality, Time to Volume.

## Example

### I-3. Select best design – Utility vs. Costs vs. Lead Time/TTM

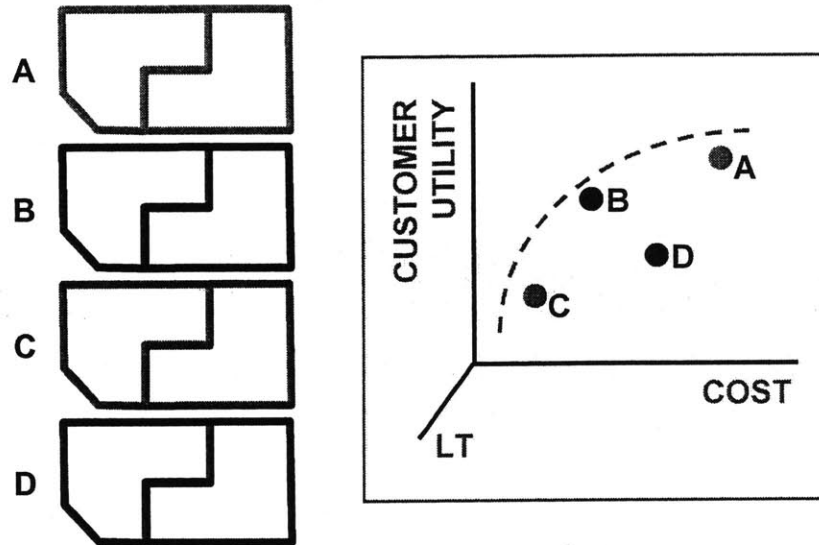


Figure 10 – A visual representation of the use of MATE-CON.

A simple explanation of how MATE-CON can be used is as follows:

1. Let's say the Black Box exists in four different versions, A, B, C and D. Each version meets different customer needs or the same needs at different degrees.
2. The value that customers perceive in each can be measured as "utility."<sup>50</sup>
3. Since meeting each different set of needs most likely may imply the use of different technology (more or fewer components or more or fewer functions), the cost of each version can be measured too.
4. Each cost-utility pair is plotted and an invisible optimum frontier becomes apparent. All dots along or closest to this invisible frontier, are the optimum cost for a given utility.

<sup>50</sup> As defined in Chapter 2.



It becomes clear then how a more objective discussion can take place. If someone argues in favor of Version D, for instance, someone else can easily argue that Version B is a better option from all perspectives (it provides more utility at a lower cost). If Marketing insists on providing more utility to customers, they become aware of the implicit higher cost. MATE-CON does not provide the right answers, but it does help sort the tradeoffs out, and point in the direction of improvement. Through design iterations, a Version E (not shown) could be devised, such that for the cost of D it provides utility between A and B. The subsequent product design, technology development or manufacturing process improvement efforts can then be focused on either improving the utility of E for the same cost, or on reducing the cost of A without sacrificing utility. Now, because the whole cross-functional team has had a say in the decision-making process, it can move on to focus their attention on reaching the agreed goal.

Figure 10 shows a third axis on the plot that Diller, Ross or Stagny do not talk about in their work.<sup>51</sup> They talk about “schedule” as one of the attributes that can be aggregated into utility. Since a satellite is rather a job-shop type of project, (1) there is no high-volume orders for the same satellite and (2) as much as customers would like to push for earlier delivery, they have to put up with one supplier, as they cannot simply go the store next door and pick up the competition’s product. For these reasons, in this industry it is not apparent that TTM and lead-time are important enough to deserve their own axis.

Further, one of the observations made both during this research and by experts in the area is that, from a supply-chain perspective in industries where customers have more power, TTM and lead-time are of the essence and usually run against cost or utility, for which an independent axis becomes useful.

Having added the time axis, however, a question rises: should it be TTM, lead-time, or a combination of the two? Thus, MATE-CON can help sort out priorities for at least two different sets of circumstances: Product Launch and Sustaining.

---

<sup>51</sup> Their respective theses have been referenced before.

- Product Launch. In this stage, the relevant costs are those related to actually designing and developing the product, hence coined “Product Launch Cost.” The aspect of time that is relevant is TTM. In other words, this analysis tries to determine how much investment is worth to introduce product to the market, and how fast it can be done.
- Sustaining. This is steady state, so all those costs associated with (repetitively) material procurement, actual transformation, and distribution and delivery, matter; they are usually lumped into a variable such as “Total Product Cost.” And, in steady state, the time aspect that matters is “Order Fulfillment Lead-time.” In other words, it becomes relevant to know whether the project (the product) will be continuously profitable given the utility provided.

This is not to say that these are two independent analyses; they are not. In both cases, Utility represents the same set of attributes, and at the time that a target value for Utility is being determined—which should be very early in the process (at the latest, when the MRD is being prepared), both analyses should be carried out simultaneously, for the decision of how much utility is possible to provide will affect both. In other words, a product may have the right attributes and the PDD team may have the luxury of resources and time so that TTM and cost are not a big constraint; this could give the false impression of feasibility. If customers are not going to accept the product at the suggested (or unintended!) lead-time, or if the cost will be prohibitive on an ongoing basis, then the second analysis fails, rendering the whole project infeasible.

Last, it is not redundant to mention that other processes recommended in this thesis are likely to be intertwined with the use of MATE-CON. In fact, it is expected that PDD cross-functional teams will become aware of this interdependence of requirements, constraints, and processes, in order to improve its effectiveness in developing products.

### **3.10 No. 9 – Apply DFA, DFM, DFT+DFR<sup>2</sup>+DFE Guidelines Earlier (I-4)**

Most PDD teams in the industry already make use of DFA, DFM and DFT. They do so usually through the selected CM, who is given blue prints and a copy of the Bill of Material (BOM) in order to assess compliance with their DFA, DFM and DFT guidelines. Also, a couple of groups seemed to be working independently on the development of Design-for>Returns and Design-for-Recycling guidelines, but were not contacted at the time of this research, as both topics were off the scope of the project. However, as stricter rules are introduced in Europe and Japan, the industry should develop an overarching strategy that covers all the previous DFX guidelines, including DFR<sup>2</sup> and DFE.<sup>52</sup>

#### **Observed Current State**

- Not all divisions within a company commit to launching a product exactly at the same stage in the PDD process. Also, it cannot be guaranteed that DFX guidelines will be included early enough in the process to make a difference. When they finally are, they have often missed the launch of the first product version.
- Improvement in the application of DFX guidelines is not pursued.
- DFR<sup>2</sup> and DFE guidelines are being developed (out of the scope of this project).

#### **Desired State**

- CM and supplier input on Assembly, Manufacturing, and Testing is included before official project commitment is stated, and even during preparation of the MRD, if possible, to maximize Cost Avoidance.
- The industry has begun to include Design-for>Returns and Design-for-Recycling guidelines as part of its DFX procedures.
- The application of these techniques is tracked (metrics) in order to comply with continuous process improvement processes (e.g. as required by ISO9000-2000).

---

<sup>52</sup> DFReturns and DFRecycling have been lumped together into DFR<sup>2</sup>, for ease of use and to acknowledge the existence of both without using the acronym “DFR” twice.

### **Next Steps – The Specific Recommendation**

1. Assemble a cross-functional team that identifies the status of DFR<sup>2</sup> and DFE, and benchmarks industry and research about formal DfX processes.
2. Define the industry's DfX process that allows for continuous improvement (include metrics).
3. Recommend the inclusion (and application) of these guidelines in the current Engineering procedures, at a stage no later than the official product launch commitment.

### **3.11 No. 10 – Begin DFL Analysis Earlier (I-5)**

Although in principle DFL could be included in the previous recommendation, as it is one more of the DfX techniques available in the market, in the case of the industry, DFL has recently gained importance, for not all products are designed to be transportable.

#### **Observed Current State**

- Packaging Engineers are often engaged in PDD with short notice (usually, when the process is close to First Customer Ship); they often have to accommodate to whatever conditions (product volume and weight, packaging) exist at that point.
- The industry can benefit a lot from earlier involvement of packaging Engineering.

#### **Desired State**

- Similar to the DfX recommendation, packaging engineering and other DFL input is included in the planning or concept design stages.
- Suppliers and third-party logistics play an important role in DFL.
- DFL takes into account DFR<sup>2</sup> and DFE too.

### **Next Steps – The Specific Recommendation**

1. Assemble a cross-functional team that does research about DFL.

2. Define the industry's DFL process that allows for continuous improvement (include metrics).
3. Recommend the inclusion (and application) of these guidelines in the current Engineering procedures, at a stage no later than the official product launch commitment.

### **3.12 No. 11 – Expand the Application of Postponement (I-6)**

Hau Lee would argue that companies can benefit a lot more from Postponement than they have so far. Also called Delayed Differentiation, Postponement can be explained in the following way:<sup>53</sup>

The features that differentiate one SKU from another should be determined as close to the end of the production process as possible in order to (1) minimize the effect of demand forecast inaccuracy, (2) improve response to last-minute customer demand changes, and hence (3) reduce total safety stock expense.

#### **Observed current state**

- In general, companies have no means to properly apply Postponement.

#### **Desired State**

- Guidelines to properly apply Postponement to the selection of components (beyond power supplies) are followed, thus minimizing total safety stock and cost.

---

<sup>53</sup> Several authors have covered the topic of Postponement or Delayed Differentiation. Hau Lee and Cory Billington have jointly produced papers throughout the 90's that talk about the incursions of HP in this topic, so the case of the HP DeskJet printer is well-known. Some sources of information on the topic consulted: (1) Lee, Hau & Marguerita M. Sasser. "Product Universality and Design for Supply Chain Management." *Production Planning & Control*, 1995, Vol. 6, No. 3, pp. 270-277. (2) Cargille and Bliss. (3) Aviv, Yossi & Awi Federgruen. "Design for Postponement: A Comprehensive Characterization of Its Benefits Under Unknown Demand Distributions." *Operations Research*, Vol. 49, No. 4, July–August 2001, pp. 578–598. (4) Lee, H. and Laura Kopczak, "Hewlett-Packard: Deskjet Printer Supply Chain", 1993. (5) Simchi-Levy. (6) Fine. (7) Ulrich, Karl T. & Steven D. Eppinger, *Product Design and Development*, 2nd edition, Irwin McGraw-Hill, 2000.

## Next Steps – The Specific Recommendation

1. Assemble a cross-functional team that benchmarks industry and research on the topic of Postponement.
2. Draw abstract principles based on the observations and explore areas beyond common components (power supplies) where postponement may be applied.
3. Define the industry's Postponement process that allows for continuous improvement (include metrics).
4. Recommend the inclusion of these guidelines as part of the PDD process and current Engineering guidelines.

### I-6. Expand the application of Postponement (Delayed Differentiation)...

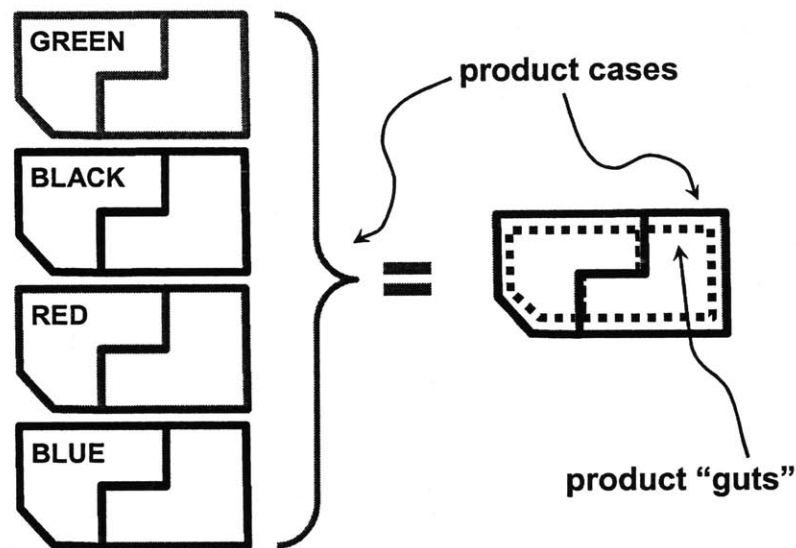


Figure 11 – An example of Postponement.

#### Example

Figure 11 explains the Nokia case. The plastic case can be removed and replaced, leaving the guts of the device intact, but entirely changing the looks of the product. This is postponement at its best: Nokia need not forecast individual demand profiles for each color but only total demand for the phone. When the product has recently been launched they can order the production of individual color cases.

## 4 A FRAMEWORK FOR IMPLEMENTATION

### 4.1 Chapter Introduction

The aspect of implementation cannot be ignored, especially because some of the recommendations presented are very likely to produce strong resistance. In view of these perspectives, this chapter presents three frameworks that address the resistance to the effective implementation of the DFSC recommendations in the industry. These three frameworks are applicable in any other industry. Coincidentally, “the three lenses on organizational analysis and action,” developed at MIT Sloan,<sup>54</sup> provide guidelines that point in the direction of the same three sources of resistance: the strategic design lens, the political lens, and the cultural lens. The connection between the sources of resistance observed and the three organizational lenses will be explained where appropriate. Further information on these lenses is given in Chapter 5.

### 4.2 A Framework to Understand the 14 DFSC Recommendations

Following the Japanese ideology of Management by Policy (Hoshin Kanri),<sup>55</sup> it is understood that DFSC recommendations have to be aligned with a typical company’s goals (such as profitability, customer satisfaction, etc.). In order to do this, several steps have been taken:

1. Identify the industry’s goals and metrics.
2. Produce a list of potentially useful supply-chain performance metrics.
3. Trace the connection between supply-chain metrics and industry metrics.
4. Identify the drivers behind the DFSC recommendations.
5. Further trace the connection between the DFSC drivers and the industry’s metrics (through the DFSC recommendations and the supply-chain metrics)

---

<sup>54</sup> Ancona, Deborah et al, Organizational Behavior & Processes. 2<sup>nd</sup> ed., South-Western, Cincinnati, 1998.

<sup>55</sup> Akao, Yoji, Hoshin Kanri. Policy Deployment for Successful TQM, Productivity Press, Portland, 1991. Course material by Chu-San-Ren, the Central Japan Industries Association, for the course “Industry-Wide Quality & Productivity Management for Mexico 2000,” Nagoya, May-December, 2000.

The first three were achieved early in the process, before any DFSC recommendations were produced. The last two have only recently been reached.

The list of specific metrics of these companies is not disclosed, so an independent list of supply-chain metrics was produced using the Supply-Chain Council SCOR Model metrics as a basis.<sup>56</sup>

<b>SC Delivery Reliability</b>
<i>On-time Ship</i>
Fill rate
Perfect Order Fulfillment
<i>Early Failures</i>
<i>Visual Defects on Site</i>
<b>SC Responsiveness</b>
Order Fulfillment Lead-Time
<b>SC Flexibility</b>
SC Response Time
Production Flexibility
<b>SC Costs</b>
<i>Std Cost (Cost of Goods Sold)</i>
<i>Inventory Carrying Cost</i>
<i>Logistics (packaging, transportation)</i>
<i>Returns</i>
Value-Added Productivity
<b>SC Asset Mgmt Efficiency</b>
Total Inventory Days of Supply
Cash-to-Cash Cycle Time
Asset Turns

Table 2 – List of supply-chain metrics. Those in italics are not originally represented in the SCOR Model metrics list.

<sup>56</sup> “Supply-Chain Operations Reference-Model,” Version 4.0, Supply-Chain Council, 2000.



After first screening, this list was reduced (not shown). This was achieved by weighting and aligning the original list with the corporate metrics. Also, the unintended notion that some of these supply-chain metrics were not very clear—despite having their definition at hand—helped in weighting the importance of the short-listed ones.

	<b>driver(s)</b>	<b>performance metric(s)</b>	<b>monetary direction</b>
<b>I-1 Cost Avoidance</b>	- Better deals	<b>(P) Tot Cost</b>	<b>CA</b>
<b>I-2 Part Reuse, Commonality</b>	- Fewer parts → both less inventory, less safety stock (through smaller variability) - fewer parts to procure	<b>(P) Inventory</b> <b>(S) Lead-Time</b>	<b>CA</b>
<b>I-3 Best Design with MATE-CON</b>	- right match offer/requirement - tradeoff utility/time/cost	<b>(P) Effectiveness</b> <b>(S) Lead-Time, TTM; Launch Cost, Tot Cost</b>	<b>RG</b>
<b>I-4 Earlier DFx (incl. DFR<sup>2</sup>, DFE)</b>	- waste reduction - fewer steps	<b>(P) Tot Cost</b> <b>(S) Lead-Time</b>	<b>CA</b>
<b>I-5 Earlier DFL</b>	- waste r - fewer steps	<b>(P) Tot Cost</b> <b>(S) Lead-Time</b>	<b>CA</b>
<b>I-6 Postponement</b>	- less SS (through smaller variability)	<b>(P) Inventory</b>	<b>CA</b>
<b>II-1 Earlier Supply Chain analysis</b>	- waste reduction - waste reduction	<b>(P) Tot Cost</b> <b>(S) Lead-Time</b>	<b>CA</b>
<b>II-2 Product-Component Lifecycle</b>	- waste reduction	<b>(P) Tot Cost</b>	<b>CA</b>
<b>III-1 Optimal Variety of SKUs</b>	- right match offer/requirement - tradeoff utility/time/cost	<b>(P) Effectiveness</b> <b>(S) Lead-Time, TTM; Launch Cost, Tot Cost</b>	<b>RG</b>
<b>IV-1 Tech Roadmapping (3DCE)</b>	- growth potential	<b>(P) Long-term Growth</b>	<b>RG</b>
<b>IV-2 SC Collaboration enhancement</b>	- growth potential	<b>(P) Long-term Growth</b>	<b>RG</b>

CA: Cost Avoidance  
 RG: Revenue Generation; RG can be CA @ min  
 (P): Primary metric  
 (S): Secondary metric

Table 3 – The drivers of DFSC and their alignment with the industry’s goals.

Finally, by tracing the connection between both sets (corporate metrics and supply-chain metrics) the supply-chain metrics were weighted and prioritized to identify the main four or five:

- On-Time Shipment
- Order Fulfillment Lead-Time
- Std. Cost (Cost of Goods Sold)
- Returns
- Total Inventory Days of Supply

Table 3 is the result of the last two steps. This table was prepared much later in the research. It presents the list of DFSC recommendations (following a numeration that is explained in this chapter) followed by three columns:

- Drivers. This column identifies the (quasi) operational mechanism by which the recommendation in question influences or drives the performance metric(s) by which it is measured.
- Performance metrics. Although the drivers and the recommendations can be measured by different metrics, one primary and, in some cases, one or more secondary metrics that could best capture the performance value were chosen.
- Monetary direction. Even before this table, it had been noticed that companies are usually reported to implement solutions that save them money, instead of focusing on or complementing them with other solutions that generate more revenue.

The independent list of metrics is fairly equivalent to the one these companies prepared for themselves. A few differences:

- Effectiveness and On-Time Shipment, Returns. Effectiveness: doing the right things versus doing things right. The SCOR metric “Perfect Order Fulfillment” is similar, but effectiveness also includes on-time shipment and returns.
- TTM, (Product) Launch Cost. These two metrics are not contemplated by the SCOR Model, and are not contemplated by the industry either. These have been raised mainly by the use of MATE-CON.

- Long-term Growth. Interestingly enough, the absence of this metric and other similar one from the scorecards and reports of most companies in the world already raises some questions. One may argue that this metric is highly abstract, or that it measures something that slips out of the control of a industry, or that other metrics capture its value already. Precisely, because these three arguments are flawed, companies fail to make decisions that impact more positively in the long run. As Fine suggested once,<sup>57</sup> a company may be “doing everything right,” like IBM, and still fail to escape a strategic trap.

This distinction that a given recommendation may only save cost or generate revenue is an important one. Saving cost has a hard-stop limit: zero cost. Although, the likelihood that all or some costs can be reduced to zero is very low; there is only so much improvement that can be accomplished in this direction. Looking at the other direction, however, there are no apparent limits—or at least not so obvious. In theory, revenue can be increased continuously if new products and services that meet hidden or new needs are continually created, if the market allows higher prices or higher volumes, or if the resources to produce more are available and affordable.

Also, it seems that those recommendations that can generate revenue can also avoid costs. In other terms, at their worst, they will reduce costs; at their best, they will generate revenue. Furthermore, while thinking about this dual potential of such recommendations, an adaptation of the graph used by Kano to explain the difference among three types of requirements in QFD can be used to explain this. (See Figure 18)

---

<sup>57</sup> Telephone interview, September 9, 2002.

## Revenue Generation vs. Cost Avoidance

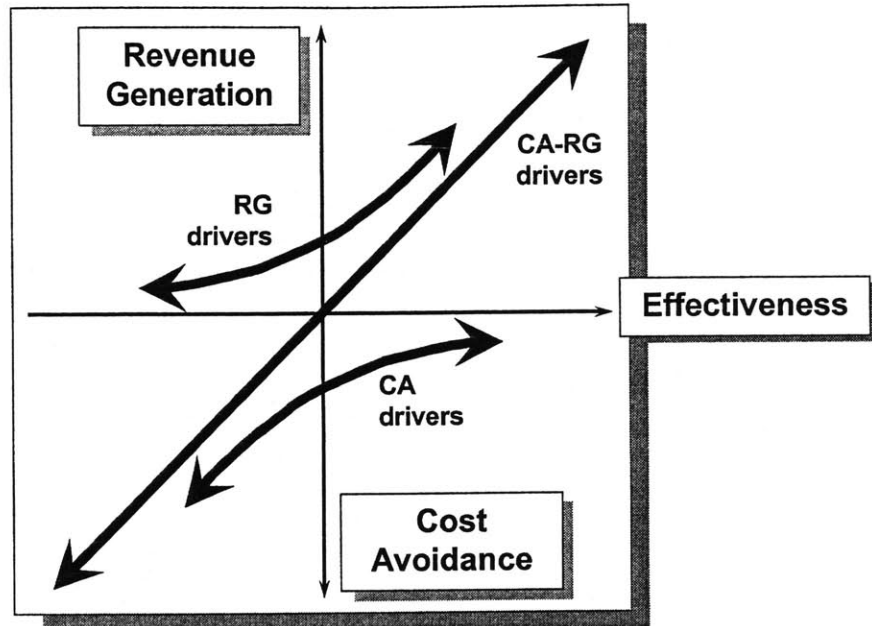


Figure 18 – Revenue Generation vs. Cost Avoidance.<sup>58</sup>

In the original image, the axis labeled “Revenue Generation” would read “Customer Satisfaction;” “Cost Avoidance” in the original case is “Customer Dissatisfaction.” The curves “RG drivers,” “CA-RG drivers,” “CA drivers” are originally “exciting requirements,” “normal requirements,” and “expected requirements.” The explanation is that expected requirements are those that customers always expect the provider to have met. If they are met, they do not generate satisfaction; if they are not met, they generate dissatisfaction. Normal requirements “satisfy (or dissatisfy) in proportion to their presence (or absence) in the product or service.” Finally, “exciting requirements are beyond customers’ expectations. Their absence doesn’t dissatisfy; their presence excites.”

<sup>58</sup> Adapted from course material by Glenn Mazur for the course “Introduction to QFD”, 2000, in turn adapted from “Attractive Quality and Must-be Quality” by Kano, Seraku, Takahashi & Tsuji, Hinshitsu, Vol. 14, No. 2 (1984)

In this case, some drivers can only save costs and have a limit on their effectiveness. Other drivers are linearly proportional to their effectiveness, and depending on how well they are being implemented, may simply save cost or generate revenue, as suggested above. Finally, pure revenue-generating drivers cannot avoid costs; they simply generate revenue.

Because this is an empirical modification of a useful plot to try to explain the duality revenue generation-cost avoidance, it is not easy to make it work 100%. However, in Chapter 6 it is suggested how this may help find other DFSC recommendations that were not identified during this research.

After this lengthy explanation of goal and metric alignment, a question remains: Why is this alignment necessary? From the perspective of the strategic organizational lens, alignment is the third strategic design process. From this perspective, alignment is “assessing the implications of strategic grouping and linking patterns for the rest of the organization’s structures and processes, and making changes to ensure that the grouping and linking patterns can be implemented effectively.” In other words, if things such as incentives, resources or goals are not aligned, “organizational patterns that pull groups and individuals to behavior that undermines the strategic intent or that pulls different groups in opposing directions” are likely to appear.

#### **4.3 A Framework to Introduce and Implement the 14 DFSC Recommendations**

From an organizational-processes perspective, change deals with power struggles and cultural changes. Through the political lens it can be understood whose power is being threatened by change, whose power should be influenced to make change, and how to do the latter while minimizing the effect of the former. Organizations, though, are also used to their “own ways of doing things,” and groups and functions in large companies usually have their own subcultures, so change efforts must also deal with this resistance. Through the cultural lens it can be understood how and which processes to modify in order to be able to sew the new processes and behaviors in place. This framework and the next deal

with these two aspects (political and cultural). An analysis of the actual observations made in this context is subject of the next chapter.

Introducing the 14 DFSC recommendations to any industry, should then be planned as a function of (1) the value these recommendations will provide and (2) the difficulty of implementation. These recommendations require full commitment on the part of the organization and mainly on the part of the intervening functions. However, in order for the various functions to commit, the political and cultural obstacles must be overcome. Besides the organizational analysis provided in the next chapter, introducing all recommendations at the same time is in fact counterproductive (from the experience of HP<sup>59</sup>). Those recommendations that provide the smallest relative value are in fact easier to accept, (1) because they require the least amount of cultural change (i.e. they are only a few steps added to their regular procedures) and (2) because they offer the smallest or no threat to those in power. Hence, working with a couple of PDD teams can be used as live experiments and a couple of small losses can be outweighed by several gains, which can in turn win credibility and support over for the change process. Those recommendations that can provide the most value are the hardest to accept, so are left until the end. With this in mind, the following four stages of implementation can be considered:<sup>60</sup>

- I. Awareness – raise awareness of supply-chain considerations in the PDD, Engineering and Marketing communities.
- II. Involvement – get involved with PDD teams to help them work out solutions to their everyday problems.
- III. Collaboration – further increase interaction; the level of trust is high enough so that the functions represented in the PDD cross-functional teams can demand more from the tools and processes implied in the DFSC recommendations.
- IV. Strategic Synergy – bring the attention of the organization to strategic positioning and clockspeed strategy: choosing the products, processes and supply chains to gain or sustain competitive advantage.

---

<sup>59</sup> Interview with two of Hewlett-Packard's SPAM (Strategic Planning and Modeling) group members.

<sup>60</sup> These four stages are the result of the abovementioned interview. Although colleagues at HP did not coin the terms, in their explanation they talked about "three phases" of implementation. A colleague then suggested that perhaps a fourth phase in which Fine's strategic tools were introduced could be added.

Figure 19 depicts the impact (value) and difficulty of implementation of the DFSC recommendations lumped in the four phases. First of all, this explains the connection between the original numeration (1-14) and the alternative numeration (I-1, etc.). More importantly, this shows how the organizational transformation can be carried out.

## Four Implementation Phases of DFSC

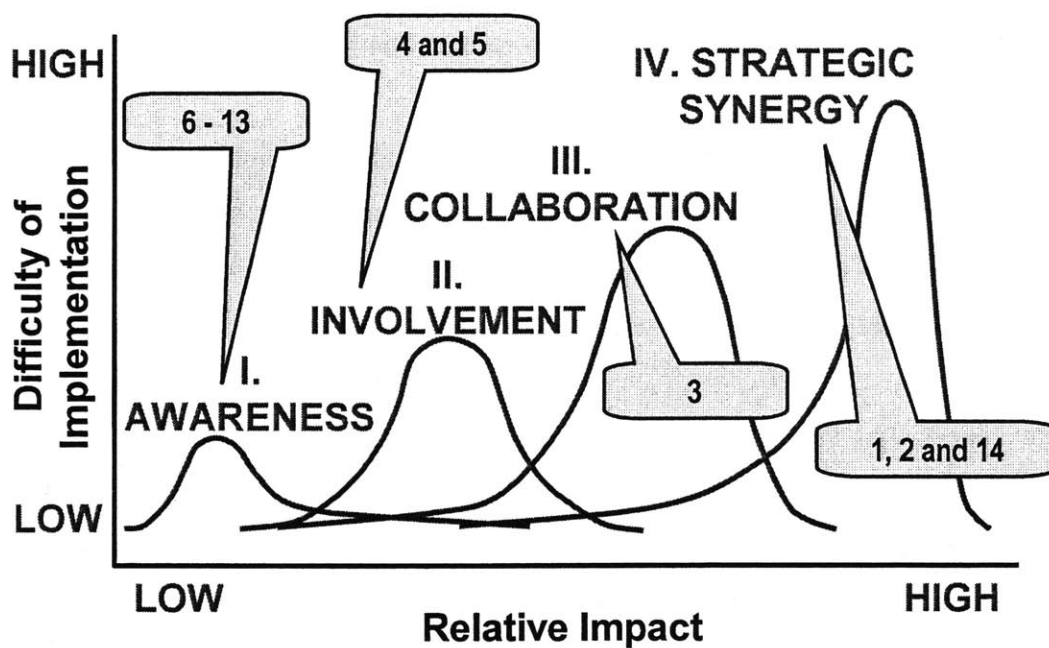


Figure 19 – Four Implementation Phases of DFSC.

This visual representation also provides an empirical understanding of the interdependence and overlap of these phases. This suggests that Strategic Synergy, for instance, does begin early in the Awareness phase. The curve itself tips off to the left under this phase; but the curve then shows that the bulk of its impact occurs much later, in what has been called the Strategic Synergy phase.

#### 4.4 A Framework to Drive Implementation of DFSC

Having a gradual process to introduce recommendations is not enough, however. Someone has to drive that process, and has to be both willing to do it and allowed to do it. This implies the need to address the political and cultural aspects in a different way.

In order to be willing to drive the process, the individuals in question must find this process not only non-threatening to their job or aspirations but must also find a benefit deriving from the time and effort (and possibly budget) they are going to invest. A single individual cannot drive all change, and regardless of whether the culture is too vertical or horizontal, a dual approach is required: top-down and bottom-up.

The top-down approach represents a “strong top-down model of change that [mixes] charismatic and tough analytic leadership by a [top individual who is] willing to make hard decisions even if these [mean] imposing personal costs on considerable numbers of current employees for the sake of maximizing the value of the firm to shareholders.”<sup>61</sup>

In the bottom-up approach “the action [is] at the workplace, involving small groups of frontline workers, supervisors, and in some cases unions or workers’ councils. Labor-management partnerships [are] formed in which workers [... join] with managers in problem-solving processes to empower workers, increase teamwork, and gain the flexibility needed to improve quality, productivity, and customer satisfaction.”<sup>62</sup>

For companies whose culture is relaxed, as it is the case in many high-technology companies, the dual approach is best. On the one hand, using the second framework can gain the implementation team credibility with the “frontline” employees on the PDD teams, showing them how DFSC can incrementally help them do their job better. The first framework, because it may resonate more with middle and senior managers who are measured by profit-and-loss contribution, shows how DFSC is aligned with their

---

<sup>61</sup> Ancona et al.

<sup>62</sup> Ancona et al.



objectives. This rationale explains the suggested composition of a DFSC implementation team. (See Figure 20)

# DFSC Implementation Team

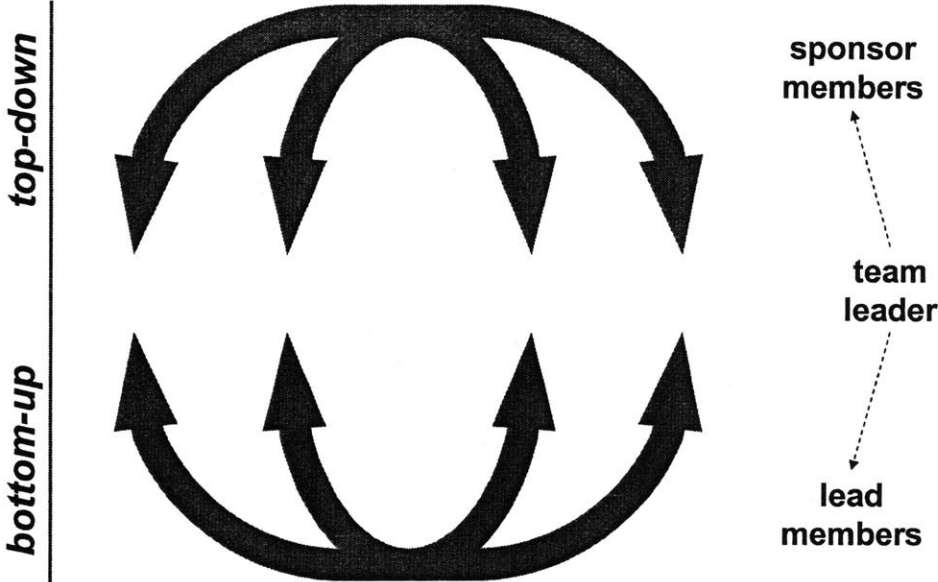


Figure 20 – The DFSC Implementation Team.

## **5 THE ORGANIZATIONAL CHALLENGE**

### **5.1 Using the Three Lenses on Organizational Processes**

#### **Strategic Lens**

The strategy of supply-chain oriented companies today is to build and run their supply chains from a holistic perspective. As mentioned before, one of their specific objectives is to engage with the product development functions and processes, since the group recognizes that earlier engagement will grant the greatest possible influence.

As discussed in the previous chapter, it is important to design a DFSC implementation team, as there are no specific jobs designed to do so. In fact, besides devising the frameworks for implementation, the mere creation of the team ensures the creation of a coordinating system to support the implementation process.

#### **Political Lens**

One of the first steps that this organizational perspective requires is the drafting of a stakeholder map (not shown). Although there were no apparent opposers, the support of some of these stakeholders was in fact contingent to the success of the project, or at least partial success or the promise of success upon completing a few stages. It was not until portfolio of recommendations was ready that others began to publicly voice support for the project. Hence this map is only a static view of what in fact was a dynamic process.

In principle, for every relationship made, an implementation team has to analyze whether the person or group in question could provide support, help make or execute the decision, or give access to those who could. Furthermore, in the case of those with little power to voice their ideas, each opportunity to interact with them to “socratically” help them come up with ideas that could improve the conceptual basis of the project has to be

taken. Their ideas can be mixed with those from people with more credibility. In this way, everyone can see how they are helping shape—and own—the project.

## Cultural Lens

Some engineering groups may see this as an intrusive effort, trying to begin to change the relaxed, entrepreneurial culture that has existed at the industry. For this reason, introducing oneself as one more on the team, who was willing to learn from them, makes it successful to help the implementation team develop relationships. It is important to always stress that there are benefits for all, and that these new processes in mind would be managed by themselves. Working with the engineering teams shoulder-to-shoulder as per Framework 2 in Chapter 4 helps the implementation team build credibility with them and minimize their perception of a threat.

## 5.2 Leading the Change Process

According to the work done by a few professors at MIT Sloan on the Sloan Leadership Model,<sup>63</sup> there are four functions one must perform when leading:

- **Sensemaking.** “Triangulates a wide variety of data about organization and stakeholders, actively surfaces others views, and creates a new map of what is happening in the group or organization.” It is about “making sense” of the environment. Gathering data through the three organizational lenses, and organizing it in a way that “makes sense.” It is also about understanding the natural tendency to infer and assume, and being aware of when it is right to believe the assumptions and when it is not. “Sensemaking is like ‘map making.’ Are maps we use useful? Different maps, different purposes...”<sup>64</sup>
- **Relating.** “Listens to others, encourages expression of diverse viewpoints, advocates own point of view to others, values and develops others, and builds

---

<sup>63</sup> Ancona, Deborah, Thomas Malone, Peter Senge, and Wanda Orlikowski, “The Sloan Leadership Model,” draft manuscript, MIT Sloan School of Management, 2003.

<sup>64</sup> Comment made by Thomas Malone in the course “15.973 Leadership Workshop: Distributed Leadership” at Sloan, 22-24 January, 2003.

networks of collaborative relationships with others.” Beyond gathering data, relating is about inquiry and advocacy; that is, about forming relationships by further asking for information and expressing ideas. Since sensemaking makes use of inquiry as well, it is often hard to distinguish it strictly from relating, but sensemaking focuses more on gathering data.

- Visioning. “Creates compelling vision for others, builds follower support, and shows the way through expressing passion and modeling behaviors that support the future vision.” It is about crafting the vision for the team, with the team.
- Inventing. “Invents new modes of work, encourages experimentation and risk, coordinates change processes, monitors results, and creates an atmosphere that helps others to produce.” Another word for it is “execution,” but in a creative way. In exercising leadership, the leader may need to “invent his way” as he finds new obstacles in the way.

However, as in the difference between sensemaking and relating, these four actions are not always distinctly separate or sequential. In this project, this was particularly true because there was no specific vision to accomplish nor any methodology that described how to go about creating a new field of knowledge. Actually, it took almost three months of continuous sensemaking, relating, visioning and inventing to figure out what finite vision the team could go after, what data would be needed, what relationships should be developed, and what tools and processes would be essential for implementation. Figure 21 summarizes the bulk of this effort, and a specific description of the actions follows:

- Sensemaking. As Figure 21 suggests, a large amount of data has been gathered to (1) understand the way each BU does product development; (2) learn about various research and works seemingly related to DFSC; (3) understand the proceedings in PDD team meetings; (4) understand the dynamics between groups and within groups; (5) identify stakeholders, their needs and their expectations; and others.

## The Leadership Process: Sensemaking, Relating, Visioning, Inventing

- **88 interviews**
- **70+ people**
- **11 weeks**
- **9 product teams**
- **8 product roadmaps**

Figure 21 – The leadership process.

- Relating. Simply gathering data would not make the production or implementation of recommendations easier, however. So, understanding that expertise, support, and influence of several people at a later stage were required, every single interview, meeting, and any other opportunity to relate counted towards building the social capital. This became much more important later, when the team (1) began to look for support from more senior managers, (2) sought audiences to start socializing the recommendations, and (3) reached the point where the creation of a DFSC implementation team became necessary. Having built the project with them made these low-cost transactions.
- Visioning. In the case of this project, visioning was a team exercise. Although the goals of the project were clear, these could not be mistaken for the specific vision (or visions) that could inspire the entire PDD organization. This project-specific vision was formed by amalgamating the collective visions of the stakeholders.

Crafting this vision was sometimes an education process: because one of the implicit objectives of the project was to teach people a more holistic understanding of supply-chain operations, the team had to communicate some of these concepts before it could solicit input on ideas for a DFSC vision. Other times, a dialogue would take place to turn their suggestions and concerns into elements of the vision. And, at the same time that the vision was taking shape, it was being shared with others. In other words, all stakeholders were being allowed to participate in the creation and edition of the vision, making the communicating and convincing stages easier.

- Inventing. Although there was no actual implementation of the 14 recommendations, there were plenty of opportunities to “invent.” Whether it was (1) tweaking supply-chain concepts to make them understandable for different people; (2) finding ways to join meetings and teams to have access to new data and resources; (3) empowering others to help the team spread supply-chain knowledge; (4) consolidating knowledge and momentum buildup into presentations shared with the organization on an ongoing basis; (5) or creating small wins in the form of tokens of support from senior managers, little by little did the team pave the path for the time when the DFSC implementation team could actually begin the implementation.

From a personal perspective, I realize that my change signature<sup>65</sup> was a major component of this process. The way I earned credibility, respect and trust seemed all to be an intertwined part of the plan. In fact, measuring the organizational change activity level is almost equivalent to measuring my effectiveness in leading this activity level. When the project took off under the wing of the DFSC team and my presence was no longer required, both curves separate. (See Figure 18)

---

<sup>65</sup> “Change Signature: Acts in accordance with personal values, builds credibility, wins respect and trust of others, and leads in a way that others recognize as authentic.” Ancona et al.

# Catalyzing Action

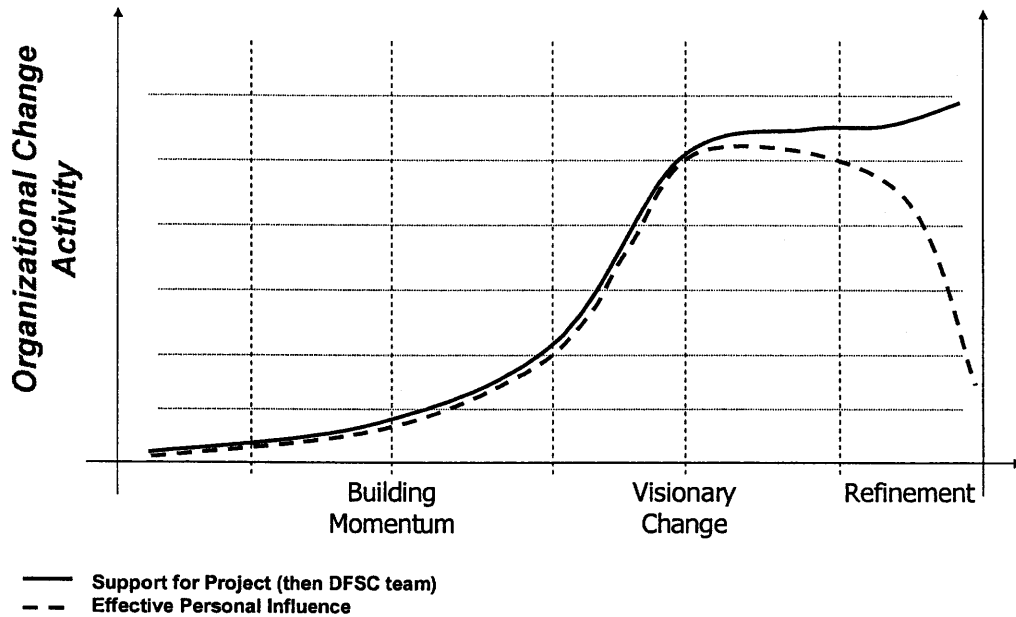


Figure 18 – Catalyzing action.

## 5.3 Evaluation and Recommendations

Measuring the achievement of the project (the production of 14 DFSC recommendations) against the original project goals gives a positive result. Other positive results: (1) the knowledge engineering groups and other PDD-related functions gained on average about supply chain; (2) the creation of the DFSC implementation teams following a dual top-down-bottom-up approach; and (3) the engagement of various stakeholders and the support gained.

It is difficult to assess how many recommendations and what percentage of each will be fully implemented. However, from the perspective of some people in the industry, it is better to be somewhat right most of the time, than to be perfectly right when it is too late.

As far as making specific recommendations to others attempting a similar project, a few come to mind:

1. Prepare better for earlier interviews. Several of the first interviews were more like experiments to assess how much data was obtainable and how the interaction should take place. Time was wasted as not enough strategizing took place then.
2. Synthesize and summarize information on the go. Towards the second third of the internship period, slides summarizing the first findings and ideas would have come handy not only to better socialize these findings and ideas but also to have a source of ideas when the time came to produce preliminary recommendations-supporting material.
3. Get help sooner. More people doing literature research would have freed more of my time for interviews and social-capital building; also, a team from the beginning would have been able to summarize more information in a shorter time.



## 6 FUTURE RESEARCH

### **More or Fewer Recommendations... or a Better Ideological Outline that Contains Them All**

The reader may have certainly identified much room for improvement and future research by now. For one, the fact that there was no implementation suggests that some recommendations may undergo subsequent revisions and modifications once they are actually applied. Each recommendation can render a process to which an entire new thesis could be devoted.

Other opportunities for future research are:

- Logical loopholes. A tree diagram can help identify whether in operations research, marketing or engineering design there are any topics that could be logically connected to the current 14 recommendations. If so, not only can the list be expanded, a more useful superstructure that holds all recommendations can be identified.
- CA vs. RG. Why is it that most companies identify solutions that only avoid costs (CA) instead of focusing on developing solutions that generate more revenue? This might be beyond the realm of DFSC, but because the supply chain would still be the means to deliver the product and generate revenue, it is highly likely that these solutions would still fall under the DFSC category.
- Other relevant SC performance metrics. Are there other SC metrics not represented here? Some of the SCOR Model metrics were purposefully ignored, mainly due to lack of access to their definitions and metrics structures. It is possible that by analyzing these metrics structures new DFSC items may be identified. For instance, can product complexity be objectively defined?
- SKU reduction analysis. A SKU reduction process that renders an “intelligent” number of SKUs is possible. What is that process? What should it look like? This topic in itself can be an entire project.
- MATE-CON with 3<sup>rd</sup> axis. Although two of the current MATE-CON research students agree that a 3<sup>rd</sup> axis for lead-time and TTM could be helpful, nobody has actually used a 3<sup>rd</sup> axis. Implementing it and reporting on its implementation would make another research project.
- Explicit DFSC process. Explicitly show the merge of QFD, MATE-CON and the 14 DFSC recommendations into one process. This is a potentially immense project that would take more than six months to carry out and test.