

Centralization of Manufacturing Processes at a Major Automotive OEM

by

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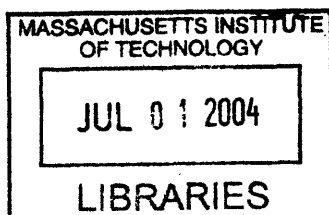
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Abstract

Ford is moving from decentralized control of manufacturing processes to centralized control. Prior to this centralization effort, product development occurred as a central function, but individual plants were largely allowed to select vendors, machine tools, suppliers, etc. for production without central oversight (other than accounting and cost control). Ford has now formed a group, manufacturing engineering, within powertrain operations (PTO), as well as analogous groups in other business units, to standardize and centralize these functions for the production of engines and transmissions. To date, the group has formally centralized machine design and purchasing with some success and a fair amount of upheaval in the daily tasks of on-site launch team members.

Two technical aspects of this shift are examined, beginning with higher communication costs. These costs are the time and effort spent relaying information to understand and select a course of action for a production network rather than a course of action for a single plant. Communication costs for Ford are shown to increase with the number of plants or platforms involved in a product or process decision. After evaluating these delays, methods to improve communication costs by modifying individual responsibilities as well as methods used by other centralized manufacturers are discussed.

In addition to modifying communication across the production network, common production processes also allow for flexible production within the network. Once plants share common equipment and processes they can produce the same products. A simple model is used to demonstrate that the network becomes more flexible and opportunities arise to improve the overall supply chain for engine production. The first order effects of this flexibility are shown to be increased utilization and fewer stockouts. However, second order effects of production scheduling and inventory management problems arise because the broader supply chain has not yet been modified to incorporate plant floor flexibility. Suggested improvements to address these second order effects are also discussed.

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1 Project Description and Overview

1.1 Problem Statement

Ford is moving from decentralized control of manufacturing processes to centralized control, largely due to the market impacts of lean¹ competitors, such as Toyota. Prior to this centralization effort, product development occurred as a central function, but individual plants were largely allowed to select vendors, machine tools, suppliers, etc. for production without central oversight (other than accounting and cost control). Ford has now formed a group, manufacturing engineering, within powertrain operations (PTO), as well as analogous groups in other business units, to standardize and centralize these functions for the production of engines and transmissions. To date, the group has formally centralized machine design and purchasing with some success and a fair amount of upheaval in the daily tasks of on-site launch team members. Ford has made less progress centralizing supplier relationships, material handling, operating instructions, labor contracts, etc.

While the current site manufacturing processes are successful they are not yet centralized or common across manufacturing sites despite corporate initiatives. The two key barriers to successfully deploying common, centralized manufacturing processes at Ford discussed in this document are:

¹ Lean manufacturing is defined as the production of goods using less of everything compared to mass production.

1. **Difficulty implementing changes required by the commonality strategy.**
2. **Mis-alignment between the commonality strategy with PTO and other parts of Ford.**

Ford's management has stated that these barriers must be overcome so that manufacturing processes operate in a coordinated, common fashion for Ford to continue as a successful automotive OEM. This thesis will examine the strategy of central, common processes and challenges to its implementation.

1.2 Executive Summary of Results

The interdependence required for common processes across manufacturing sites leads to higher *Communication Costs*. These costs are the time and effort spent relaying information to understand and select a course of action for a production network rather than a course of action for each plant. Communication costs for Ford are shown to increase with the number of plants or platforms involved in a product or process decision. After evaluating these delays, methods to improve communication costs by modifying individual responsibilities as well as methods used by other centralized manufacturers are discussed.

In addition to modifying communication across the production network, common production processes also allow for flexible production within the network. Once plants share common equipment and processes they can produce the same products. A simple model is used to demonstrate that the network becomes more flexible and opportunities

arise to improve the overall supply chain for engine production. The first order effects of this flexibility are shown to be increased utilization and fewer stockouts. However, second order effects of production scheduling and inventory management problems arise because the broader supply chain has not yet been modified to incorporate plant floor flexibility. Three suggested improvements to address these second order effects are discussed:

1. Transition the supply chain to a pull system where possible to emphasize lead time reduction and lower inventory levels.
2. Modify business processes within the overall supply chain to support new product introduction at existing plants.
3. Work with suppliers to contract for flexible delivery of parts to the network of plants instead of contracting for delivery to individual plants.

Finally, issues of cultural change around the switch to central control are also addressed. The most significant of these changes comes from the reduction of local autonomy. This is a necessary result of the common strategy since standardization is intended to allow problems to be solved more easily by creating several replicas of the common manufacturing system at different plants, allowing the root cause of a malfunction to be better identified. However, such standardization implies the elimination of different ways of thinking or approaching tasks to the greatest extent possible by reducing local autonomy.

The importance of modifying employees' expectations around this change is discussed. In particular, Ford employees do not expect to decide *what* product he or she will manufacture (they accept that a central authority will assign products to particular plants), but employees have come to believe that they have significant autonomy in *how* (by choosing local processes) they produce that product. In order for central control of manufacturing processes to succeed, the mindset of *how* things are produced must be slowly and methodically moved to the same framework as *what* things are produced through a consistent dialogue over an extended period of time.

1.3 Organization

The layout of the remainder of this thesis as follows:

Chapter 2 provides a general overview of Ford Motor Company

Chapter 3 discusses the organizational structure of PTO.

Chapter 4 addresses Ford's use of common manufacturing processes.

Chapter 5 examines the supply chain implications of centralized engineering control.

Finally, Chapter 6 presents a summary and final recommendations.

2 Introduction

2.1 Ford Motor Company²

Ford Motor Company, which recently celebrated its 100th year anniversary, is a global company with two core businesses, the production and sale of automobiles as well as financial services related to automotive ownership and leasing. The automotive business includes both cars and trucks (Ford is the market leader in truck sales) while financial services is primarily composed of Ford Motor Credit Company, a wholly owned lending company, and The Hertz Corporation, an indirect, but wholly owned renter of automobiles.

Ford Motor Company is perhaps the largest firm in the world controlled by a single family. While its equity is publicly traded on the NYSE, the corporate charter is designed to allow the Ford family to hold a majority of votes with a minority equity position. To this day, the Ford family still holds adequate equity to exercise majority control at any shareholder vote.

2.1.1 Automotive Business

In 2002, Ford's brands included Ford, Mercury, Lincoln, Volvo, Jaguar, Land Rover, and Aston Martin. Total worldwide sales of these vehicles reached 6,973,000 units. Substantially all of Ford's cars, trucks and parts are marketed through retail dealers in

² The bulk of this operational information was obtained through publicly available SEC filings.

North America and through distributors and dealers outside of North America. As of January, 2003, the approximate number of dealers and distributors worldwide distributing the Company's vehicle brands were:

- Ford (13,000)
- Mercury (2,141)
- Lincoln (1,561)
- Volvo (2,500)
- Jaguar (787)
- Land Rover (1,808)
- Aston Martin (100).

In addition to the products Ford sells to its dealers for retail sale to end consumers, Ford also sells cars and trucks to its dealers for sale to fleet customers, including daily rental companies (e.g. Hertz), commercial and government fleet customers, and leasing companies. Ford's sales have been roughly 25% fleet and 75% end consumer from 1998 to 2003.

Ford also provides its customers with after-the-sale vehicle service and products, such as maintenance and light repair, heavy repair, collision, vehicle accessories and extended repair service products. In North America, the Company markets these services under the Quality Care brand and markets original equipment replacement parts under the Motorcraft brand.

The Company's principal competitors are General Motors Corporation, DaimlerChrysler Corporation, Toyota Corporation, Honda Motor Corporation, and Nissan Motor Corporation, Ltd. Toyota Corporation in particular is Ford's most aggressive competitor. It has been taking market share from Ford, to the tune of 0.8% in 2003 in the United States with Toyota selling 60,000 more cars globally than Ford to reach number 2 in worldwide market share for the first time.

2.1.2 Financial Services Business

Ford Motor Credit Company operates as an automotive finance company. It provides vehicle and dealer financing in 36 countries to more than 11 million customers and more than 12,500 automotive dealers. Ford's profits over the last few quarters have come primarily from this unit. The other major portion of financial services, Hertz, operates as a daily renter of cars, primarily to end consumers. This thesis focuses on Ford's automotive business and the financial services arm will not be discussed further.

2.1.3 Powertrain Operations

This document will look most closely at the powertrain operations unit, where I spent seven months gathering information for this research. The powertrain operations unit (itself a subunit of the automotives business) at Ford Motor Company designs and produces engines and automatic transmissions³ for use in Ford's cars and trucks.

³ Ford no longer produces manual transmissions. That activity was spun off into a joint venture in the late 1990's.

Powertrain Operations' or PTO's design activities take place primarily at facilities in the United States and Western Europe. The corollary production network of assembly and casting facilities, where engines and transmissions are produced, consists of 26 plants. Ford has eight engine plants, four casting plants, and three transmission plants in North America:

1. Chihuahua Engine Plant (Mexico)
2. Cleveland Engine Plant 1 (USA)
3. Cleveland Engine Plant 2 (USA)
4. Dearborn Engine Plant (USA)
5. Essex Engine Plant (Canada)
6. Lima Engine Plant (USA)
7. Romeo Engine Plant (USA)
8. Truck Modular Engine Plant and Annex (Canada)

9. Cleveland Aluminum Casting Plant (USA)
10. Cleveland Casting Plant (USA)
11. Windsor Casting Plant (Canada)
12. Woodhaven Forge Plant (USA)

13. Livonia Transmission Plant (USA)
14. Sharonville Transmission Plant (USA)
15. Van Dyke Transmission Plant (USA)

There are six engine plants, one casting plant, and two transmission plants in Europe:

1. Dagenham Engine Plant (UK)
2. Bridgend Engine Plant (UK)
3. Merkenich Engine Prototype Operations (Germany)
4. Dunton Engine Prototype Engine Operations (UK)
5. Valencia Engine Plant (Spain)
6. Bordeaux Transmission Plant (France)
7. Halewood Transmission Plant (UK)
8. Cologne Forge and Die Cast Plant (Germany)

In addition, Ford has a single casting plant (Metcon Casting Plant) located in Argentina and two plants in Brazil (Taubate Engine and Transmission Plants). Plants are managed based primarily on their geographical location, with North American plants reporting to staff in Dearborn and European plants reporting to staff in Dunton.

2.2 Production of a Modern Automotive Engine⁴

The production of a modern engine is a complex and amazing task that the average consumer takes for granted. This overview is included to help the reader understand the products and processes that are the subject of this research.

An engine plant primarily consists of machining lines and assembly lines. The machining lines use sophisticated machine tools to produce the primary metal subassemblies of the engine, most commonly:

- cylinder head
- cylinder block
- crankshaft
- camshafts
- connecting rods.

The figure below shows an assembled four cylinder engine with various subassemblies labeled for reference (from Eggert, 1998).

⁴ Much of this information was taken from the excellent engine production overviews provided in Eggert (1998) and Blanchette (1998). The reader may want to peruse these documents for additional technical details on the production of a modern automotive engine.

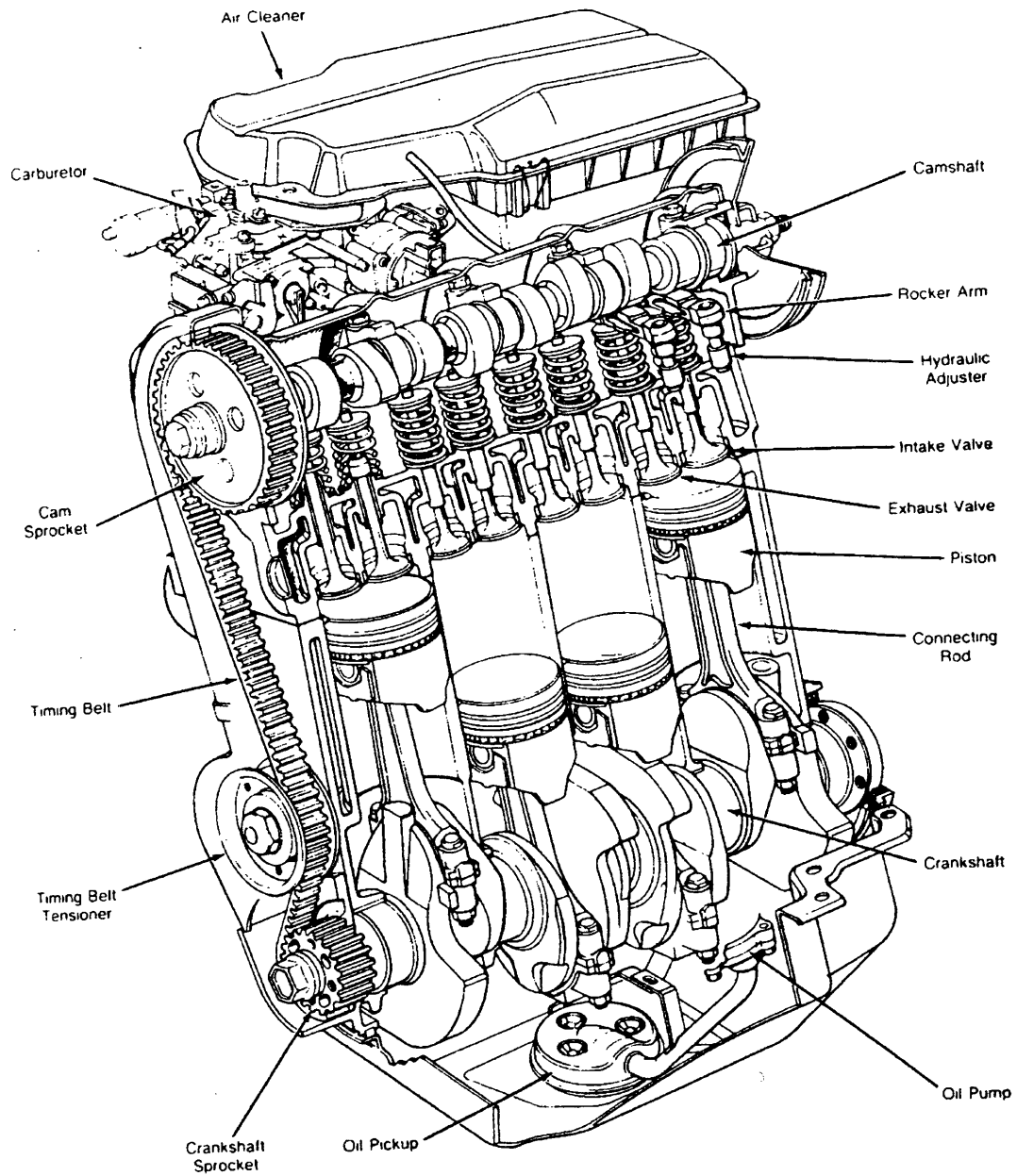


Figure 2.1 Representative Automotive Engine (from Eggert, 1998).

The machining line begins with cast or forged parts and machines them according to engineering drawing requirements. This is done by using large machine tools that perform operations such as milling, drilling, reaming, tapping, honing, broaching, grinding, and polishing. The machine tools are quite large, often 200 cubic feet or more in volume. A line that machines one component for an engine may have 20 or more of these machine tools, each designated by an OP or Operation # (such as OP 10 for the first operation or OP 40 for the fourth).

Engine plants also have a final assembly line where the components from the machining lines are assembled along with other necessary subassemblies (such as wiring harnesses, gaskets, oil pan, etc.) that are purchased from external suppliers. The final assembly line consists of a motorized system that moves materials along the line past various stations. Most of the stations consist of an operator installing components by hand, or with the assistance of a machine that tightens down several bolts at once (referred to as a multi-spindle machine, where each spindle tightens one bolt). After assembly, the engine goes through one or more functional tests and is shipped to a vehicle assembly plant for installation into a car or truck.

The focus of this study is a newer generation of Ford engine plants consisting of three machining areas (cylinder block, cylinder head, and crankshaft) and a final assembly line. The other machined parts (camshafts and connecting rods) are purchased from outside suppliers, along with a variety of other subassemblies.

3 The Structure and Culture of Ford PTO

Like any other company, the heart of Ford Motor Company is its employees, the more than 350,000 people who arrive each day to ultimately produce vehicles for sale to consumers. The majority of these employees have worked most of their careers at Ford, an organization under the control of a single family for 100 years. For this and other reasons, the culture and structure of Ford PTO appear both distinctive and pervasive to an outsider such as myself.

3.1 Formal Organizational Structure

Before diving into Ford's culture, it is first helpful to understand the formal organizational structure of PTO and its geographic footprint. The central engineering organization as well as other central functions, such as supply chain scheduling or accounting, are headquartered in Dearborn, Michigan, USA and Dunton, England while manufacturing facilities are spread around the world (see the list in Section 2.1.3).

Geography aside, PTO can be broadly divided into the following organizational units:

- Manufacturing Engineering – Responsible for manufacturing processes.
- Manufacturing – Responsible for production.
- Business Office – Responsible for investment and product management decisions.
- Product Development– Responsible for product characteristics.

These groups are managed through a hierarchical management system and do not formally “link up” until the senior management level. This means that issues between the units (e.g. Manufacturing Engineering and Manufacturing) are resolved using peer relationships not reflected on the organization chart or by elevating the issue to a fairly

high level where formal links exist. This structure appears to be part of the reason that plants have utilized local semi-autonomous decision makers and that each plant has worked to create the best production system for its product(s) rather than a single, common production system.

3.2 Culture

Having discussed Ford's organizational structure, we will now use a framework for examining its culture. The framework is Schein's three level entity model (Schein, 1997). This framework makes use of what can be observed by watching individuals and then inferring how those individuals make choices. Its usefulness will be as an evaluation of how and why Ford makes choices. We will first define Schein's three levels and then look at examples of each at Ford, before finally drawing conclusions based on the framework.

- 1. Artifacts** – These are the initial clues to values and assumptions at an organization. Artifacts are particularly important at a culture as strong and old as Ford's.
- 2. Espoused Values**– These values represent what employees and the firm say about their culture. They may or may not accurately reflect actual values.

3. **Underlying Assumptions**– At the deepest, and most instructive, level we have assumptions. Assumptions shape values, lead to observable artifacts, and determine context for decisions.

We can now consider insightful examples of all of these categories at Ford PTO. First, the material artifacts that I observed at Ford included:

1. Each meeting begins with a discussion of safety. This is an interesting artifact because it was intentionally introduced to lead to an espoused value. This artifact is used to reinforce the culture of safety at Ford. The fact that this and other artifacts have contributed to making Ford a safer work environment by changing espoused values points to the power of artifacts.
2. People are classified by their organizational allegiance (e.g. engineering, powertrain manufacturing, controller's office, etc.) When you meet an employee for the first time you will generally learn two facts about him or her, name and organizational affiliation. This artifact breaks a huge company down into subgroups where employees feel strong allegiance.
3. Acronyms are commonly used. This artifact points to the strength of the culture at Ford. Strong cultures often use a kind of shorthand, for example acronyms, in their communications. Employees are able to depend on the context that culture provides to communicate quickly but outsiders are often unable to keep up with the rapid exchange of information because they don't know the code of acronyms

and other shorthand. This pattern tends to bind insiders together and reduce the influence of outsiders.

The espoused values that accompany these artifacts include the corporate mission⁵ statement:

- Our Vision** To become the world's leading consumer company for automotive products and services.
- Our Mission** We are a global family with a proud heritage passionately committed to providing personal mobility for people around the world. We anticipate consumer need and deliver outstanding products and services that improve people's lives.
- Our Values** Our business is driven by our consumer focus, creativity, resourcefulness, and entrepreneurial spirit. We are an inspired, diverse team. We respect and value everyone's contribution. The health and safety of our people are paramount. We are a leader in environmental responsibility. Our integrity is never compromised and we make a positive contribution to society. We constantly strive to improve in everything we do. Guided by these values, we provide superior returns to our shareholders.

In addition, other values I observed at PTO include:

1. **Customer Focus.** At PTO, it is important to know who is receiving your product and to try to meet their needs. However, note that the espoused value of strong customer focus has a different meaning at PTO than at a retail automotive dealership. Because PTO employees are several layers upstream from end consumers, they view other Ford employees as their customers, not the consumers who purchase cars.
2. **Quality is Job 1.** The quality of a product is more important than its profitability.

⁵ Taken from <http://www.ford.com/en/company/about/overview.htm>.

3. Safety is Job 0. Safety comes before any other priority, even quality. Ford has artifacts that work to reinforce this value, such as beginning every meeting by discussing safety (mentioned above).

Finally, we can think about the underlying assumptions that drive these observed artifacts and espoused values. The first assumption I will discuss is that PTO employees regard Ford as all powerful and all encompassing; it is literally their world. Employees at PTO deal with other Ford employees or with suppliers focused on serving Ford, not external consumers. As previously mentioned, this means that the espoused value, know your customer, within PTO translates into knowing the other Ford organizations since they are PTO's only customers. This assumption is also reinforced by the number of employees and the hierarchy and formality that employees use to deal with each other. I also found that many employees have extended families (spouse, parents, children, etc.) who are also Ford employees, so that Ford includes both work and home.

This assumption of totality leads to employees who are highly committed to Ford. Employees, particularly union employees, are unlikely to leave Ford. In addition to relatively high financial compensation, employees attach their self-worth to their careers with Ford. This means, for example, that Ford can train employees with valuable skills and experience less turnover than other organizations. I believe it also contributes to the strong work ethic observed at Ford during crises.

However, this assumption also has negative consequences. Insomuch as Ford dominates employees' worldview, companies or ideas external to Ford have less validity. Below is an excerpt of an article (Sawyer, 2002) that discusses this assumption when an acquaintance of the author leaves Ford.

"[Ford's CEO] was right in the sense that the auto industry *is* closed to ideas and people outside the inner circle. It's populated by folks unwilling to think about, much less try, new things. So OEM's lose people like my friend—and countless others like him—every day for the simple reason that working from outside the box isn't encouraged or allowed. And their 'hare-brained' ideas go with them. Ultimately it's the reason that automakers drop to their knees with nauseating regularity when the market shifts, forcing them to grasp at seemingly radical ideas that had been delivered on the proverbial platter long before. It doesn't have to be this way, but I doubt it will ever change."

The assumption that Ford is all encompassing is connected to our second key assumption, that success at Ford is a zero sum game where internal groups fight over a fixed pie.

Because Ford is seen as all encompassing and the validity of external organizations is reduced, groups tend to focus on the resources and rewards available at Ford rather than those external to Ford. This has been true since Ford's inception, dating back to Henry Ford I and his grandson Henry Ford II.

David Halbersham (1986) chronicled Ford and noted that both the original Mr. Ford and his grandson often created "contests" pitting one manager against another to see who was more worthy of a promotion or plum assignment. This approach succeeded in the first half of the twentieth century when engineering prowess allowed Ford to steadily move upmarket with its vehicles. It also served the company well during the boom years between World War II and the oil crisis when the US industry functioned as an oligopoly

of General Motors, Ford, and Chrysler, but has been less successful since the market shifts that followed the 1974 North American oil crisis.

The artifact that most strongly reflects this assumption is the classification by people into organizational buckets. People in each category are focused on optimizing their category against others rather than all categories together. Also, employees seem to derive the most pride from success at their plant and/or the success of the product produced by their plant, reinforcing their local identity. This assumption has a strong link to Ford's history of decentralized plant control and the rewarding of each plant based on its success rather than the success of all plants as a group. There is actually more focus on comparison between Ford plants than between Ford and its competitors, e.g. a GM plant. This assumption can serve as a barrier to a more centralized decision making process.

3.3 Three Lenses on PTO

Having described the culture of PTO using Schein's three levels, we can now think about the implications of PTO's culture for a strategy of common, centralized processes. To do this, we will examine how culture affects insiders' viewpoints on three different aspects of their jobs. Those areas are *strategy, politics, and culture*. Within each area, Ford's organizational behavior will encompass ways of doing things that have worked well enough to be considered valid and, therefore, to be taught to new members as the correct way to handle those problems (Schein, 1997). We will see that approaches that do not fit

these teachings will be difficult to implement, despite their apparent validity to an outsider.

3.3.1. Strategic Lenses

Since this project focuses on a strategic initiative to bind separate production facilities together, let us begin with an examination of the strategic lense.

One of the important issues being determined is exactly what it means to have a centralized common manufacturing system. This is a challenging and difficult question to answer and I observed debates as to how the strategy should be formulated even within the single subgroup of central engineering. Often these debates focused on technical details of what level of similarity is necessary to have common manufacturing processes. There is also regular discussion of who is responsible for the overall success of the projects, central engineering or the plant staff. Finally, there has been some discussion of whether central engineering is responsible for the overall manufacturing process or just the hardware necessary to make and assemble parts (leaving individual factories to make their own decisions about training, human resources, operating systems, etc.). Whether or not central engineering applies to all aspects of production, or just machine tool design and layout, will have significant strategic implications.

I believe that central engineering's focus on technical challenges belies the fact that the difficulties at Ford with centralization are more cultural than technical. There are to be sure technical difficulties, how to use a single grinding system across many engines or

how to meet different environmental regulations in different countries with the same equipment, but the engineering culture at Ford attacks these problems ferociously and will eventually conquer them.

The issue of key stakeholders drives many of these cultural challenges. The two largest stakeholders from an individual plant's viewpoint are its union and the corporate managers reviewing its metrics. Plant management has a clear motive to be successful in the eyes of both corporate decision makers and union leaders. Success for corporate managers is defined as meeting metrics of utilization, quality, and on time delivery within a fixed budget. The union is primarily concerned with the quality of work content, compensation, and confidence in employees' continued livelihood.

These two sets of interests collide most strongly when centralized production makes available capacity to produce engines a commodity. Under a differentiated system each plant can produce only a few items and this means that unless those products are completely eliminated, the plant will maintain some level of employment. However, if any plant can produce any product then significant over-capacity could result in the complete closure of one or more plants rather than just a slowdown or partial layoff. Under the flexible production scenario, overall costs are reduced (assuming it is less expensive to run n plants at full utilization than $n-1$ plants at partial utilization), but the union's goals of continued employment for all members are more likely to suffer if a plant is closed.

3.3.2. Political Lense

The politics of the centralization strategy are split across two major subgroup distinctions with Ford PTO, *Functional Subgroups* and *Geographic Subgroups*.

I observed the largest political tension between central engineering (i.e. manufacturing engineering) and manufacturing (the collection of PTO plants). As previously mentioned, employees have a strong allegiance to their subgroup and tend to identify with one, but not both, of these two functional subgroups. This strong identity split is exacerbated by the fact that the two groups are evaluated on different metrics. Although the following is a simplification, it is generally true that the central engineering group is responsible for the purchase and installation of equipment (which are largely fixed costs) while the plants are responsible for some installation of equipment and the production of engines (which are largely variable costs). These metrics are not always aligned and can lead to political tension between the groups over optimizing fixed versus variable costs or other tradeoffs.

In addition to functional subgroup distinctions, I also observed a strong geographical distinction at Ford PTO. Specifically, employees tended to perceive important differences between Ford of Europe and Ford of North America, and to identify as a member of one but not both of these groups in addition to being part of a single functional subgroup. These differences are strong enough that internal discussion boards for general topics almost always have employees taking a stance on some issue that

involves a polarization between North America vs. Europe, for example emissions standards on the two sides of the Atlantic or the popularity of small cars versus SUV's. These divisions make it difficult to answer cross-Atlantic commonality questions. For example when a machine tool must be sole sourced for both continents, how does one choose between a European and a North American supplier?

Because of the size of these political subgroups (thousands of employees in each subgroup), implementing consistent manufacturing standards across groups that consider themselves distinct and have different ways of doing business has required significant energy and surfaced the tensions between these groups. Developing a centralized system that achieves Ford's best interests as well as the interests of each political group has been a significant challenge and will require time and persistence.

3.3.3. Cultural Lense

We have already seen that cultural affinity within Ford tends to be for a smaller subgroup or geography, not simply Ford as a corporate entity. I have often stated in presentations to catch audiences' attention that there are only three kinds of people at Ford...us, them, and those other people. I have found this cultural view to be broadly applicable within Ford PTO, particularly in manufacturing. For example, I was based at the Cleveland manufacturing site, and within meetings, employees were generally classified with one of three labels:

1. Anyone based at Cleveland is one of “us.”
2. Corporate staff or other folks based in Dearborn, MI are referred to as “People Up North” and anyone traveling back and forth talks about “going Up North.”
3. Finally, people at other plants are specifically referred to as “Those other people.”

This cultural sub-grouping seems to be fairly general across Ford facilities that I have visited. For example, Manufacturing Engineering, which is based in Dearborn, has “us”, European Engineering (also called I-engine), and everyone else. At Romeo Engine Plant, the world is divided into us, “People Downtown” (corporate) and those other people. The largest cultural impact of this view that Ford employees can be categorized into “us” and “them” is a strong tendency towards local decision making and pride in local versus corporate operations. This has many benefits, such as entrepreneurial thinking or quick action, but it is not well aligned with Ford’s current attempts to centralize manufacturing processes.

3.4 Organizational Evaluation and Recommendations

Given my conclusion that Ford’s culture makes it inwardly focused, loyal to its own, and suspicious of outsiders, the question is how to use these facts to Ford’s advantage. Let us consider alternative ways we might use these conclusions to continue Ford’s implementation of common processes.

3.4.1 Use Existing Culture

Schein (1997) suggests that subcultures are typically in conflict within larger organizations, but that organizations tend to have common assumptions that supercede the conflicts when a crisis occurs or when a common enemy is found. Ford is clearly an expansive company that contains distinct cultural subgroups. It is a matter of opinion as to how much conflict there is between subgroups but there is clearly some. One option is to use an external enemy to unify internal organizations. The market has clearly presented a suitable enemy in Toyota. Toyota is currently taking market share from Ford, an unpopular fact at a company as proud as Ford with a long record of success. In addition, Toyota can be used to symbolize the loss of American manufacturing jobs, a deeply unpopular trend among Ford manufacturing employees. I believe that linking the centralization strategy to overtaking Toyota could serve as a powerful motivation tool.

3.4.2 Modify Existing Culture

In conjunction with the utilization of existing culture or as an alternative option, managers can seek to modify the culture to better mesh with the strategy of centralization. This is certainly not an easy task. In fact, Schein (1997) states that “if one wishes to distinguish leadership from management or administration, one can argue that leaders create and change cultures, while managers and administrators live within them.” He goes on to state that culture is the primary reason for failure to change in the corporate environment. Because “we tend not to examine assumptions once we have made them but to take them for granted, and we tend not to discuss them.” If we are forced to discuss them, “we tend not to examine them but to defend them because we have

emotionally invested in them” (Bohm, 1990). I certainly found this to be true during my time at Ford. For example, when I told my colleagues at Ford that I thought it was an insular culture they tended to react defensively.

It is also important to realize that centralization versus local autonomy is not an all or nothing affair. If Ford clearly identifies areas where employees still maintain local autonomy it can emphasize the positive rather than the loss. Employees still can, and should, provide input into standard processes. Laying out such an input system may help employees feel like they still have enough say while gaining the benefits of others' best practices.

Finally, I believe that one step in the right direction would be to provide formal incentives to help employees think beyond their local subgroups. It would be a difficult adjustment, but metrics could be introduced to reward plants for accepting innovation from other plants and outsiders and for implementing their improvements as common processes at sister plants. As always, any change in metrics can result in gaming or dissatisfaction, but incentives provide the opportunity to retain the strong culture that binds employees together but to modify it in such a way that centralization across subgroups is encouraged.

4 Commonality Initiative

As mentioned in the introduction to this thesis, although the commonality initiative applies to both transmissions and engines our scope here will be limited to the production of engines.

4.1 Benefits and Costs of Commonality

Like all strategies, common control of manufacturing processes by a central organization has both benefits and costs. Many of the benefits of commonality can be classified as economies of scale. It is expected that having a central group solving a set of problems at each engine plant once rather than each plant devoting resources to the problem will reduce costs. These cost reductions come from both the reduction of technical labor to solve the problem and from a decrease in tooling costs from purchasing a standard set of machine tools. There is also cost avoidance through reuse of common processes and tooling to produce a later product. This is because Ford has already completed much of the engineering work during its initial process development and must now simply “turn the crank.” In addition, there should be fewer capital expenditures as common tooling will sometimes be available for a new product line, avoiding the need to procure new tooling with every product launch. Furthermore, cost savings can be recognized from increased production flexibility within the supply chain. These savings are discussed in detail in Chapter 5.

While more difficult to value, improvements in quality have the potential to create the largest cost impact as well as a significant revenue growth (i.e. market share increase). Rigorously evaluating processes when they are candidates for commonality gives staff a high quality baseline to which they will commonize. This will improve quality across Ford by bringing manufacturing quality up to the highest levels in the company. The next step is then to use the resources available as part of the commonality strategy to adopt industry best practices and reach the highest levels of quality in the industry. These improvements should be recognizable as lower warranty costs and a decrease in "things gone wrong" complaints.

The costs of commonality are often more difficult to quantify than the benefits. One that can be measured is the time required to complete projects under a centralized system versus processes that are locally managed. The cliché "time is money" is highly representative of the lost time associated with the engineering and administrative process of implementing engineering changes. Commonizing means there will be fewer unique machine tools, assembly lines, or processes that require changes, but when changes are required, more plants (and potentially more vehicle programs) will need to assess and process the change. It is generally believed that this will cause the actual cost of making engineering changes to increase. One can imagine the time and person hours necessary to have five facilities agree on a problem statement, find a "good enough" common solution, and then implement the solution is greater than the sum of each facility responding to a similar problem individually. As engineering changes begin to dominate

the cost savings from production improvements⁶ and delays in product launch counter the increased market share due to higher quality, these disadvantages can make commonality less appealing. Commonality at Ford is too new to assess market share increases from its quality gains (and this is an inherently difficult endeavor), but the next several sections will look at the communication costs associated with commonality.

4.2 Commonality at Ford PTO

Like any organizational shift, the switch from decentralized processes to centralized processes can be assessed largely on the success in managing the change from one way of doing business to another. Because this shift is large in scope and affects thousands of employees, we will focus on a single example of the first type of problem discussed in Section 2.1:

Difficulty implementing changes required by the commonality strategy.

As mentioned in the previous section's discussion of costs and benefits, common processes can be a competitive advantage. Companies like Toyota and Intel have leveraged common processes running across a network of plants to apply improvements quickly across products and to help new plants or new products ramp up quickly. However, the change from differentiated specialized processes to common processes can be difficult to implement.

⁶ Engineering changes account for 30-50% of the cost of a die in the US Automotive industry (Clark and Fujimoto, 1991). Given this proportion a small increase in engineering changes could have a large effect on capital equipment, such as dies.

One example of how this implementation has been difficult for Ford is in the increased communication any organization requires for common processes. At Ford PTO, a portion of the final decision making authority for each process or product lies at the production facility. For this reason, many, if not all, decisions on common processes require consensus among a group of employees from all of the stakeholder plants plus the central engineering organization. This section discusses how this distributed authority, with an emphasis on centralized, common processes, has led to implementation difficulties due to increased communication.

4.3 Communication Costs of Standardization

One of the apparent reasons, both in PTO and within other Ford organizations, for frustration after the adoption of commonality is increased delay. Prior to central control of common processes, a single decision maker considered each manufacturing decision as an opportunity to optimize his or her plant. With the advent of a central organization and standardized practices, every decision is an opportunity to optimize a system of plants. Discovering the global optimum requires the exchange of information between decision makers and experts at each plant whereas the decentralized system allowed decisions to be made with little or no exchange of information between plants. This exchange of information requires time, money, or both and is therefore termed a *communication cost*.

In addition to the minimum communication cost required to exchange information, some time may also be spent debating the appropriate decision. To reach a global optimum, it

is often necessary to prevent individual plants from reaching their local optima (e.g. your facility loses \$1 MM, mine gains \$2 MM and we net \$1MM by making a change at both plants—a better local optimum for you might have been to do nothing and gain \$0 MM at both plants). Given that employees may be trained to focus on local optima and that their incentives may be based on local optima, it is clear that a significant amount of time can be spent choosing a decision in addition to communicating information.

4.3.1 Evidence of Communication Costs

Before attempting to understand the exact causes of communication costs within Ford, it would be valuable simply to demonstrate that they exist and try to quantify the communication costs of PTO's commonality strategy. To accomplish this, the WERS (Worldwide Engineering Release System) database system was used to search for correlations between communication volume and commonality. WERS is used to track the approval of any request to modify a product (processes do not have a corresponding database⁷). Approval requires, at a minimum, the concurrence of central personnel managing the product and plant personnel managing production.

To search for evidence of communication costs, 808 distinct WERS requests for changes that were initiated between 11/4/1999 and 8/18/2003 within PTO manufacturing engineering's V-engine group were examined. Table 4.1 shows that almost 90% of WERS requests affected a single facility.

⁷ There is no centralized process manager. Instead, all central control of processes comes primarily through manufacturing engineering's oversight at the product level.

Table 4.1 Distribution of WERS Requests.

Number of Plants Involved	Number of WERS Requests
1	703
2	98
3	6
4	1

This distribution suggests that:

1. Despite a shift to centralized manufacturing processes, most changes are not being formally managed across plants.
2. The lack of multi-plant initiatives may point to the difficulty of managing such changes.

Figure 4.1 shows a graphical representation of the time required to complete a change as a function of the number of plants where the change is being made. The data clearly suggests that changes involving more than one plant require more time to reach concurrence. This is a measure of the amount of time required to agree upon an appropriate resolution, not the amount of time required to implement the solution.

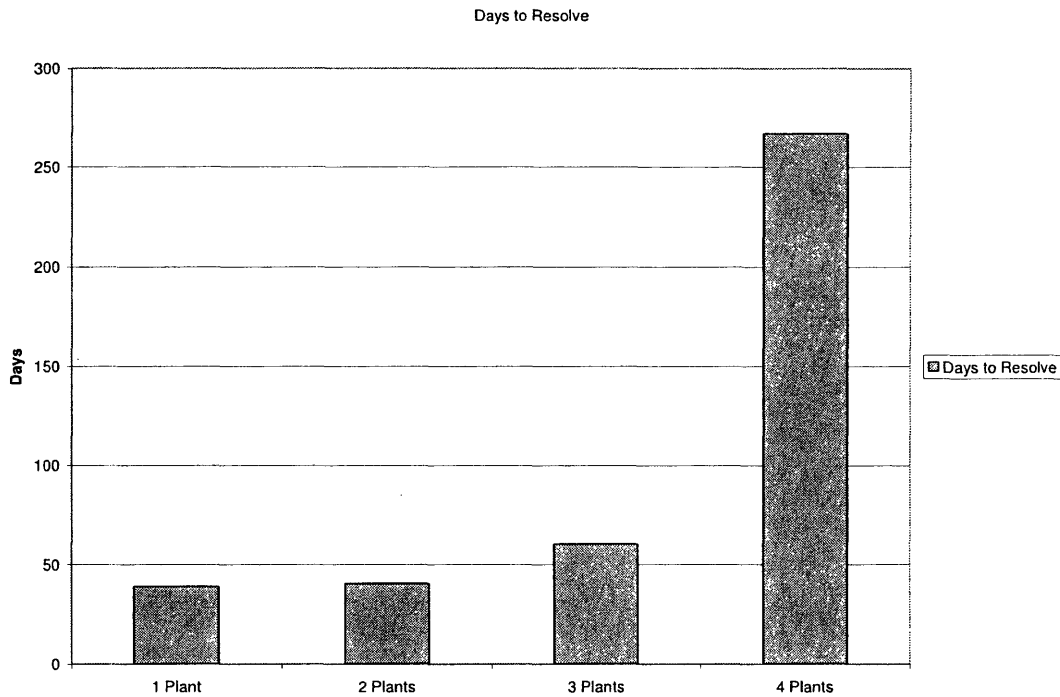


Figure 4.1 Average Number of Days Required to Resolve an Engineering Change Order as a Function of Plants Implementing Change.

This result is not unexpected and has been previously demonstrated within Ford's product development organization (Sahutske and Cratty, 2003). Their Figure 16 (p. 87) is shown below as Figure 4.2, demonstrating an increase in time required to resolve a WERS issue when a part or subassembly is linked to more than one vehicle platform (as opposed to the PTO analysis which looks at more than one production facility irrespective of how many vehicle platforms are involved). Although the two sets of data examine different dimensions (number of products on a platform versus number of plants using a process) both demonstrate communication costs increasing as the network of plants or platforms grows.

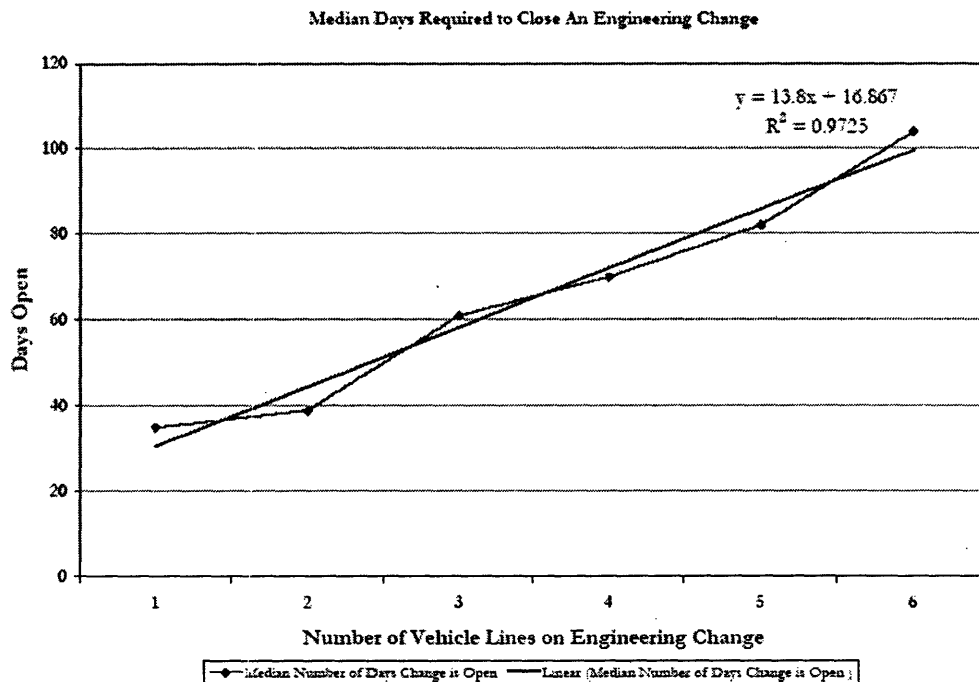


Figure 4.2 Average Time Required to Resolve an Engineering Change Order as a Function of Platform Dependence (from Sahutske and Cratty, 2003).

To attempt to understand this phenomenon, we can examine one incident in detail to determine if it fits our expected pattern of increased communication costs to exchange information and reach a global rather than local optima. While such anecdotal evidence can not be conclusive, it is quite useful in this case.

As an example we can look at a WERS concern which covered engine connectors. The existing engine connectors required mating forces, applied by hand, of greater than 75 N. A change in these connectors was initiated to meet a new specification requiring that engine connectors require 75N of force or less to install.

To solve this problem, an engineer recommended that all 2005 Model Year engines be modified to include wiring harness connectors that met the lower force standard. This issue was first entered into Ford's engineering change management system in August of 2002. This change was initially considered part of the Duratec series program plan and was therefore managed by the Duratec program. In addition the concern was routed to local decision makers at each of four facilities (Cleveland Engine Plant 1, Romeo Engine Plant, Windsor Engine Plant, and Essex Engine Plant) that needed to add new equipment to support 2005 Model Year engines.

Cleveland Engine Plant 2 (CEP2) was also producing a Duratec family engine, but on an older line with no plans for large capital improvements. CEP2 pointed out that because they produce the same Duratec product, they would have to rework 38 hot test stands to accommodate the new connectors. While it might make sense from a supply base and commonality perspective to have a single connector supplied by vendors and maintained aftermarket, CEP2 was concerned about its financial performance as a stand alone entity and therefore had a disincentive to bear the cost of upgrading these test stands.

Soon afterwards, Romeo Engine Plant (REP) pointed out that they too had a conflict. They would need to use some of the same assembly and test hardware to produce an additional engine whose current intake manifold would not accommodate the new connectors. In order for the change to be implemented across facilities, the intake manifold subassembly would have to be modified in addition to whatever changes were needed to directly support the new connectors.

Unfortunately this intake manifold was also used on a third engine program. While the third engine was not originally slotted to be part of this modification, it would also have to accommodate the change in order to continue sharing a manifold with REP's second product, something deemed important because of Ford's strategy to share processes and product subassemblies across plants and platforms.

By the end of September, almost 60 days had passed and no resolution to the problem was yet apparent. By now, most of the engine plants in North America were involved in the connector design. Around this time CEP2 noted that like REP, they too had a second product being handled at their facility. Because having two slightly different engine connectors to manage would increase the complexity of their engine builds, CEP2 asked that all products under its roof being included in the requested change, increasing the number of products pulled into the vortex of connector modification from one (Duratec) to four (Duratec, U204, J56, J16L).

Another month passed and by the middle of October, it became important to reach a decision as at least one 2005 model year product was moving close to job 1 and significant risk was being incurred because the tooling to handle either the new or old connectors was becoming a critical path item.

By November, local ergonomics authorities at facilities began receiving samples of the new connectors to assess them on a plant by plant basis. By this time, four months had passed and it was still not clear how or if the new connectors would be introduced.

By December, several plants rejected the change and stated that they would not use the new-style connectors. Unfortunately, because these plants shared products with plants still attempting to implement the change, allowing products to be produced with the old style connectors and the new style connectors would have increased the number of wiring harnesses on a single product from 17 to 34 types. A few weeks after this decision was reached the rejecting plants acquiesced and agreed to continue considering the new connectors.

By February, CEP1 logged a note that they had already implemented the change in their new line expected to produce job 1 later that year and that if the change was now not made that costs would be incurred to retrofit the assembly line to the older connectors. By the second week of March, it appears that sites and products to support the change had been sorted out, but now various programs began debating cost allocations for the necessary changes. This debate did not concern how much should be spent in total to make the change, but how much of the cost each program should be charged. Over the next several months these costs were discussed and by June of 2003 the change was finally approved, 10 months after being first logged.

In sum, this issue consumed 10 months and many person-hours to implement a change on a an electrical connector that probably makes up .0001% of the cost of an automobile and was proposed more than two years in advance of the product shipping to the consumer. This was not an issue dominated by technical engineering constraints. Instead, it appears that much of the time required to resolve this issue was spent communicating information across the network of plants and debating the relative advantages and disadvantages for the network of various solutions

4.3.2 Potential Solutions

The discussion of communication costs is not intended to vilify common processes or standards. It simply serves to illustrate an important issue. Communication on common processes should no more be stopped than discourse on safety training. Instead Ford must find a balance between communicating information through a production network and performance of the network.

As an attempt to address this issue, steps are being taken at an Ohio manufacturing campus to share staff between four manufacturing facilities located within a mile of each other. Jobs will be restructured to share responsibility for technical decisions across products, processes, and plants. The hope is that this will result in difficult decisions being made within one team or by one person rather than through argument across groups. This decision is based, in part, on evidence that two Canadian plants that currently share staff in this fashion have lower than average communication costs. It is

also hoped that this first step will allow Ford PTO to move forward on sharing staff on a much broader basis (e.g. regions of North America or product families).

5 Supply Chain Implications

5.1 Potential Advantages of a Flexible Standardized Manufacturing System

In the process of implementing a strategy of common and central manufacturing processes, Ford PTO has also been able to add substantial flexibility⁸ to production processes at engine plants. Previously, a plant generally had machine tools to produce a single product, but now because machine tool designs are shared across plants, the same plant with new, common machine tools has the potential to flexibly produce a variety of products. In Ford's case, substantial effort has also been devoted to making the switchover time from one engine or engine subassembly to another short enough so that Ford can economically produce batches of product as small as one.

Many potential advantages of a flexible production system like the one outlined above have been described over the last several decades including:

1. Demand smoothing (Jordan and Graves, 1995)
2. Risk reduction through redundancy (Corbey, 1991)
3. Reduced capital expenditure requirements (Najarian, 1992)
4. Increased utilization (Jordan and Graves, 1995)
5. Reduction in lost sales (Jordan and Graves, 1995)

⁸ Jordan and Graves (1995) define flexibility in this context as "being able to build different types of products in the same manufacturing plant or on the same production line at the same time."

While this flexibility offers substantial advantages in managing supply chain execution and investment costs, it is a good example (as detailed below) of the second kind of problem discussed in the introduction of this thesis, that is:

Mis-alignment between the commonality strategy and other parts of Ford.

In this case, Ford PTO's manufacturing engineering organization and personnel at various engine plants have worked quite hard to conquer a variety of technical challenges and introduce flexible machining and assembly to the plant floor. However, this effort does not have a well matched counterpart in the myriads of information systems and business processes that control the use of those machines. A modern Ford Engine Plant will have significantly more flexibility than its predecessor, and this is an important step forward; but, that flexibility may not be used because no one has set out to make Ford's supply chain processes aware of flexible manufacturing. There is a mis-alignment between the common process strategy on the plant floor and the many other supply chain processes in other parts of Ford.

5.2 Ford's Engine Supply Chain

To better understand this apparent mismatch between Ford's flexible manufacturing and the rest of its value chain, let us examine Ford's supply chain for engines. The engine supply chain is driven by Ford's larger supply chain for automobiles (see Figure 5.1). These systems are configured as "push" systems⁹. A push system is based on building

⁹ An alternative method of production is known as "pull." In a pull system customer orders are filled from production rather than from inventory.

inventory to a forecast of future customer orders and then filling customer orders from that inventory.

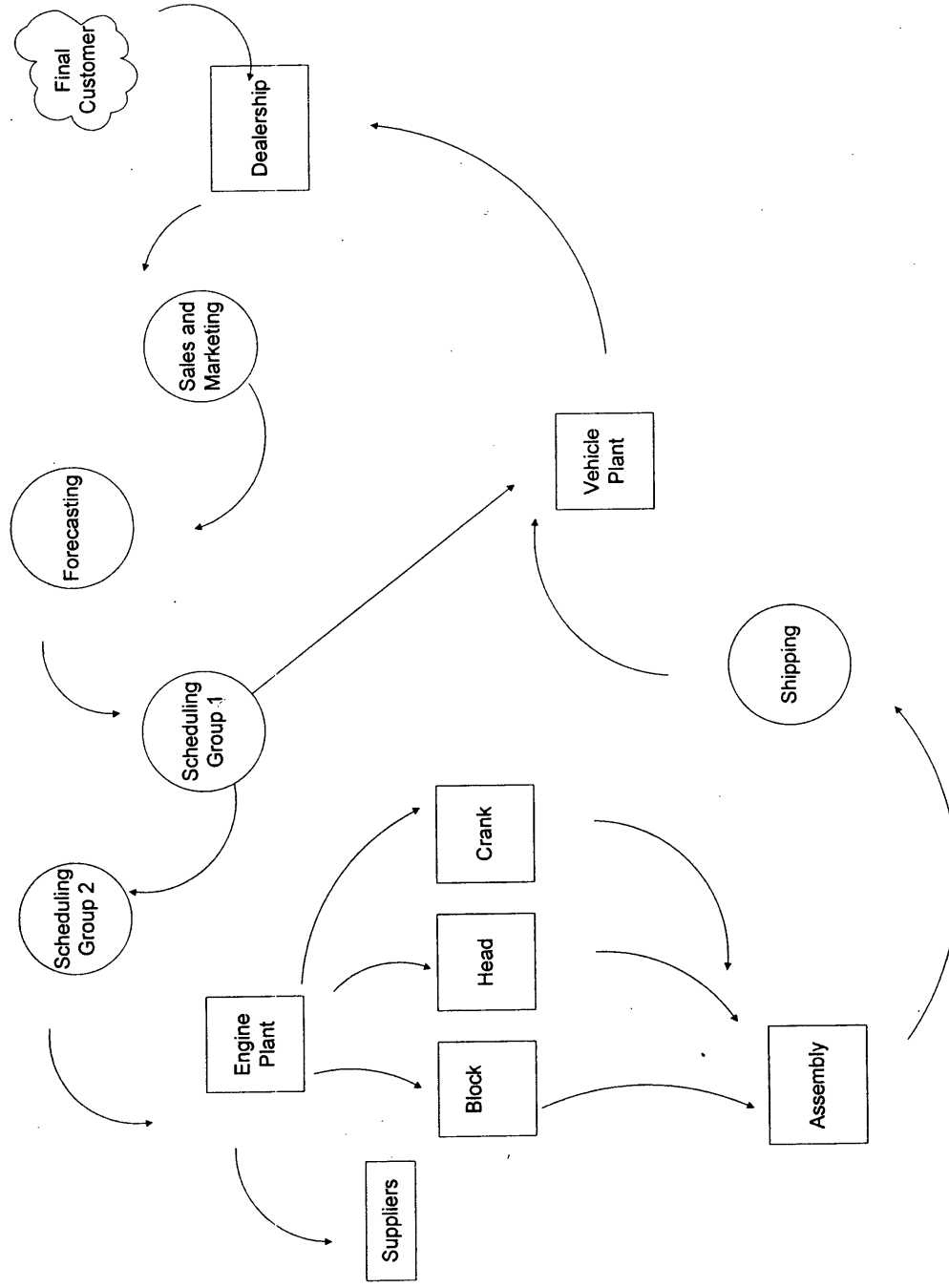


Figure 5.1. Basic outline of Ford's engine supply chain and ordering process.

Much of the mismatch between the flexibility provided by PTO's commonality strategy and the rest of Ford's production system is due to this system of building engines to stock inventory rather than for sale to customers and the corresponding high volume of inventory that must be kept on hand. This mismatch can be explained in terms of two variables:

- Changeover – the time needed to complete a set of business processes and begin producing a new product at a facility. This changeover is on the order of months or years.
- Lag – how quickly the plant can respond to *consumer* demand through feedback from its business processes. The lag response can be approximated by the total vehicle cycle time (elapsed time from customer order to dealership delivery of vehicle) which is on the order of weeks or months.

These two time periods should be closer to the time required to changeover machine tools at a flexible plant, to better utilize the flexibility available in Ford's newer production systems and avoid the mismatch. To understand why this is true, imagine a simple thought experiment, where the flexibility on the plant floor is used in the context of the current supply chain.

To begin our hypothetical scenario, we imagine that we are plant managers and our plant is running below capacity because of low demand for its product but that other Ford products are in high demand and suffering stockouts. To remedy this situation, we decide to begin producing one of the high demand products at our flexible plant—this will match our available capacity (or supply) with consumer demand.

At this point, we begin the changeover necessary for our plant to produce the new product. Because we need to ensure that our product is of the highest quality before releasing it for sale to consumers, there are a variety of business processes to ensure that no product is released prematurely. These business processes, though, are all designed with the fundamental assumption that an engine factory has *no flexibility*. Since retooling an existing facility takes many months, it has always been accepted that the business processes and decisions required to go from prototype to saleable product will take months or years. This means that although our machine tools can switch between products with as little as the flick of a switch, our corporation needs more than a year to verify the new production. So, we can see that while manufacturing flexibility is the crucial first step, we need business processes to follow.

Given this scenario, and the cyclical nature of the automotive industry, an attempt to add a new product to our plant might not be undertaken because of the wait time required to produce our new product. Instead, we may choose to use overtime to produce additional product at other facilities already producing the high demand product and not add a new

product to our flexible facility. This dilemma outlines the problem of *changeover* within the current supply chain.

To continue this experiment, imagine that we proceed and introduce our new product so that we are now scheduling production volumes of our original product plus our new product. At this point, we need feedback from consumer demand to schedule our production and decide how much inventory we will hold¹⁰ of each product. Again, our flexible plant holds the key to giving customers the Ford products they want, but we also need adaptive business processes beyond the four walls of our manufacturing facility.

Figure 5.1 shows that customer orders and inventory travel a path through numerous business units and functions within Ford and its distribution channel (independent dealers). While the exact times for each process are proprietary, the overall travel time is between two and three months. This suggests that the lag from when a customer gives information to a dealer to when a plant can respond to this information is also weeks in length. Having waited on the order of a year to changeover our flexible plant, we will now likely have inventory problems as we try to forecast demand and schedule our production weeks before the product exits the supply chain for final end consumer purchase. We may choose to hold high levels of inventory to prevent stockouts in direct conflict with corporate mandates to hold low levels of inventory, but a better solution is designing business processes that can more quickly feed back information to our plant.

¹⁰ Remember that our system is build to stock and requires us to hold inventory for customer orders.

I hope this thought experiment gives the reader, as it did me, the impression that an attempt to use a flexible plant to produce multiple products could well be unsuccessful. But, this lack of success can happen even when the technical aspects of flexibility work flawlessly but when the higher business process and overall supply chain need to be modified as the next logical improvement of our supply chain.

5.2 Engine Supply Chain Model

To take our thought experiment one step further, we can use a simple model of a supply chain simply to show how the system might behave under various scenarios. This model simulates a simple system of three plants. Initially, each plant produces one product, but a single plant has the ability to become flexible and produce two products. The demand for products is based upon a simple random walk algorithm, and the primary variables of interest are the changeover required to begin producing a new product and the lag required for the single flexible plant to respond to consumer demand. The output of this model is the actual demand, actual supply, lost sales, plant utilization, etc.

Let us look at the simple scenario of comparing the flexible system above with an identical network of three plants with no flexibility. To compare these networks we will create 10 realized demand patterns based on the same forecast information and compare how the two networks will perform across those 10 situations. For these scenarios, our flexible plant spends the capital to add an additional product whenever lost sales reach 25% in a given month. This changeover to flexible production requires one month to take affect and there is no lag between actual demand and production—all demand in a

given month is observed by the network. In an actual Ford production system, the network is larger, and both changeover and lag are longer and variable, but this highly idealized example is still illustrative.

Table 5.1. Average results for a 3 plant production network over 36 months.

	Monthly Production	Monthly Demand	Mean Utilization	Monthly Lost Sales
Flexible	2748	3177	85%	378
Inflexible	2686	3177	83%	432

Table 5.1 shows average results for the flexible and inflexible networks over the 10 demand scenarios modeled. These results show that this particular configuration increases utilization and production while reducing lost sales, as expected. Given a more detailed network we could compare the costs of implementing flexibility to the dollars of increased profit. It is also worth noting that even the flexible network does not have complete flexibility. There are lost sales even with utilization below 100% because every plant can not produce every product and so some capacity sits idle.

Figures 5.2 and 5.3 show graphically the difference between the two networks for a single simulation of 36 months. These figures show that once flexibility is enabled due to lost sales in month 2, the flexible system always has equal or superior performance to the inflexible one, as we would expect.

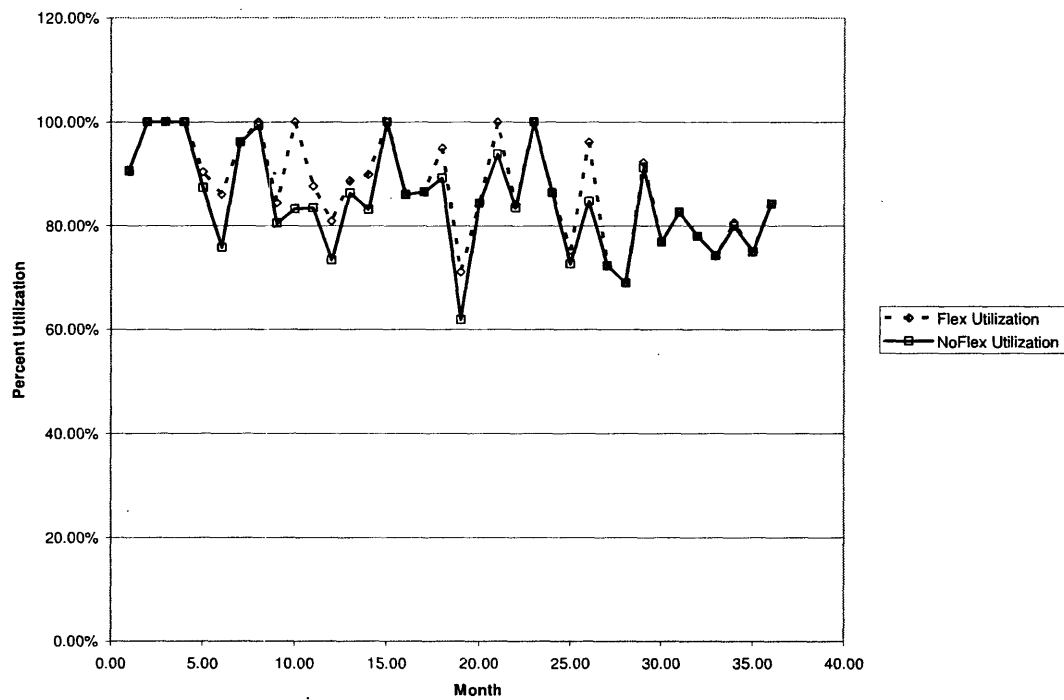


Figure 5.2. Utilization of a Flexible and Inflexible production network over the same 36 months of demand.

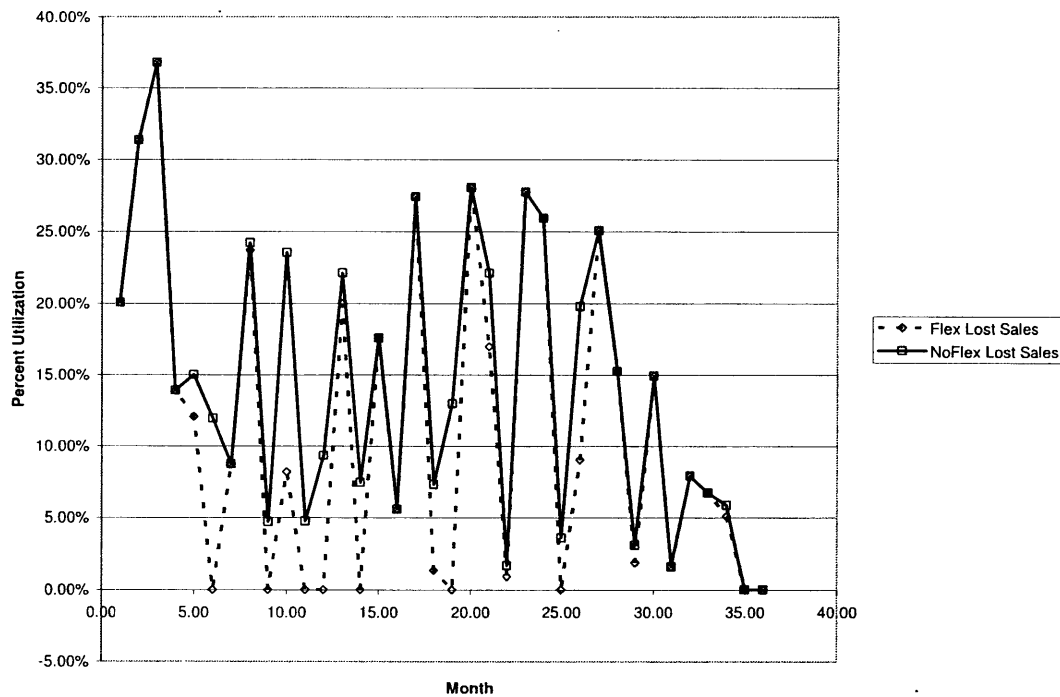


Figure 5.3. Lost Sales of a Flexible and Inflexible production network over the same 36 months of demand.

In summary, flexibility can be modeled fairly easily at a high level. Various other features, such as overtime and transportation costs, would need to be added to create a more realistic model appropriate to Ford's network of engine plants. However, a system such as this can and should be used¹¹ to find the appropriate tradeoff between the expected benefits of adding flexibility to a network and the costs one expects to incur.

5.3 Implementation Challenges

Now that we have a sense of the difficulty in utilizing the floor level flexibility within the larger supply chain, it is reasonable to ask why. Why does it seem that Ford (and many

¹¹ A simplified model was created for this research because of time constraints. The necessary data for a more complicated model to better approximate Ford's production network is not readily accessible to an outsider researcher.

other manufacturers) designed such inefficient processes? The answer is that they did not design inefficient processes, they accumulated them.

Many of these processes are based on decades of assumptions about business, customers, employees and the hodgepodge of quick fixes and special cases that were yesterday's improvisation but have been passed down as gospel to the current generation of workers. Michael Hammer spent years at Chrysler conquering this issue within its supply chain and has written an article (Hammer, 1990) discussing the issue.

Hammer notes that many of these processes stem from the Industrial Revolution, when specialization of labor and economies of scale pushed out the craftsman style of cottage industries. To reach economies of scale, work was designed as a sequence of separate tasks and employed a series of separate entities or silos to track its progress (e.g. Ford's engine supply chain). These elaborate systems and functional silos to control those who actually do the work were reinforced after World War II. Then, the main concern in the U.S. was growing fast without going broke, so businesses focused on cost, growth, and control. At that time, the population of entry-level employees was rich but society lacked well-educated business professionals, and companies thus designed a hierarchy of control systems to channel information up to the educated few who presumably knew what to do. A good analogy for this design might be the QWERTY keyboard, which was designed to slow typists who might jam its analog keys. Clearly, the U.S. and global business and labor markets make many of today's hierarchical and siloed organizations unnecessary

and inappropriate, just like a modern digital computer has no need of a keyboard designed to slow typists, but we have retained our inefficient keyboards nonetheless.

In addition to the accumulation of assumptions and workarounds, the widespread adoption of complicated ERP and MRP software systems can hinder the modification of a supply chain. These systems are of staggering size, cost¹², and complexity and though they may speed up current business processes, they have also been likened to pouring liquid concrete over those business practices. Once millions of dollars and years of careers have been spent codifying current business practice, change can be difficult and unwelcome.

Our discussion of the doom and gloom surrounding antiquated, inefficient business processes might give one the impression that Ford will never be able to change its ways. However, this is clearly not the case. Of all the companies that Hammer could have cited (e.g. Chrysler) in his discussion of success with radical business process change, he discusses a resounding success at Ford in detail (Hammer, 1990).

In the early 1980's, when the American automotive industry was in a depression comparable to that at the turn of the twenty first century, Ford searched for ways to cut costs. One of many departments targeted for cost savings was accounts payable. Accounts payable in North America employed more than 500 people, and management aimed to reduce this by 20% through improving processes and computer systems.

¹² Austin (1999) notes that sales of ERP software in the mid 1990's exceeded \$3 B annually.

Apparently, Ford management was enthusiastic about this plan, until it compared itself to Mazda, a recently acquired Japanese subsidiary. Mazda's entire global accounts payable organization consisted of 5 people! Even after adjusting for Mazda's smaller revenues, the difference was shocking and Ford realized that its target should be no more than 100 accounts payable employees. In making this decision, Hammer notes that the employees at Ford had the courage to know better than "to attribute this discrepancy to calisthenics, company songs, or low interest rates." Given our discussion of Ford's deep rooted pride and inclusive culture, one can appreciate the importance of this first step.

To achieve the auspicious goal of reducing accounts payable by hundreds of employees, managers first analyzed the existing system, which probably had roots in decision made when most of the current population had not yet been born. The system called for paper documentation to be generated repeatedly for a single order, one document to authorize purchase, another for financial records, a third to note that the order had been received, etc. At the end of this process was accounts payable, working furiously to match the purchase order against the receiving document and the invoice and issue payment.

Given the opportunity for human error when each transaction must be recorded numerous times, shipped, sorted, collated, and then matched, the department spent most of its time investigating discrepancies, holding up payments, generating documentation, and frustrating vendors.

Rather than try to speed up an inefficient process, Ford decimated the current system and instituted “invoiceless processing.” Purchasing information is now entered into an on-line database and when the goods arrive, they are accepted or denied based on this single set of information. No additional documents are generated that must then be matched and discrepancies investigated. Instead Ford reduced costs by 75% and eliminated discrepancies between the financial and physical record systems.

The point of this example is to show that large manufacturing companies with a long legacy of processes (specifically Ford) can change their way of doing business and achieve dramatic improvement. In this case Ford made an important cultural shift to enable this change. Hammer notes that accounts payable traded one cultural assumption “we pay when we receive the proper invoice paperwork” to one that was more appropriate for its new competitive environment, “we pay when we receive the proper goods.”

What is needed to see a radical change and subsequent improvement in Ford’s engine supply chain to match the one that occurred in accounts payable? First, the change needs the attention of senior leadership. Ford’s culture is one of status and hierarchy and a problem’s importance will be closely related to its sponsor’s status. Second, Ford must have the courage to again make the leap that where competitors outperform it is due to better business processes, not nationality or artificially depressed foreign currencies. Finally, Ford must again trade cultural assumptions. Instead of believing “we build engines to meet our utilization and inventory targets,” Ford must believe “*we build an*

engine when a customer wants it.” Ford has clearly accomplished such tasks before and can do so again.

6 Conclusions

Having pointed out challenges that arise under central control of manufacturing processes, one might ask if these challenges suggest that Ford should reverse course and return to more local control of processes. While this is open to debate, the issues we have covered should not lead the reader to that conclusion. Common manufacturing processes have been used as a competitive advantage at other companies (including Toyota, Ford's leading competitor) and have led to successes at Ford as well (reduced investment costs, shortened schedules, etc.). Remember that we have focused on the complexities and next steps required by this strategy rather than what has already been successfully completed. Thus, our investigation is not a criticism of the strategy or implementation, but rather an attempt to look for the next step forward.

Let us then have a final discussion of how Ford might approach the new challenges that accompany the benefits of commonality.

6.1 Local Autonomy and Centralization

In some ways, how local employees perceive control is more important than the actual level of central control. If they regard a policy as too restrictive, it will be resisted no matter how useful the policy. Ford has a long history of local decision making, local identity, and entrepreneurship within its plant network, and the move from a set of local plant operations to a single network of plants can be seen as a loss of autonomy.

Klein (1989, 1994) has previously noted the phenomenon of loss of autonomy through interdependence and the need for autonomy to have a motivated workforce. She states that a major work system design objective has been to maximize individual or work group autonomy so as to increase workforce commitment and to humanize the workplace, but that operations management has focused on introducing standards and rigorous control. It would appear the two are in conflict, since process control increases the level of coordination required and decreases autonomy. Because organizational theorists (Blauner, 1964) have even argued that employees *require* some level of discretion and autonomy to function well, the question becomes how to balance autonomy and process control.

In an industrial setting autonomy is typically related to pace and work methods. In particular, Ford's adoption of central process control has removed many decisions about manufacturing design, layout, pace, etc. from local employees. This high degree of standardization reduces not only technical variation, but also social variation. It requires that various groups (different plants in Ford's case) behave in similar ways with similar social structures for the systems to work identically. If each plant has a different, autonomous way of handling preventive maintenance, shift rotation, or even lunch breaks it can reduce the similarity of processes across the network.

This is required because standardization is intended to allow problems to be solved more easily. Since there is less variation in the system and several replicas of the manufacturing system exist at different plants, the root cause of a malfunction can be

better identified. However, such standardization implies the elimination of different ways of thinking or approaching tasks to the greatest extent possible. Herein arises the contradiction with autonomy. Autonomy requires individual differences while standardization seeks to eliminate those differences.

It is my belief that success will require a steady dialogue with employees about these changes to decision authority and a reframing of local responsibilities. Section 3.4 has already discussed methods for using or modifying the culture at PTO to smooth the transition to centralized processes. Furthermore, because examples exist at Ford of employees willingly ceding decision power we know that is possible to have decisions made either by local plants or by a central authority. For example, no Ford employees expect to decide *what* product he or she will manufacture. Instead, they understand that a central authority will use a defined process to assign products to particular plants. However, employees have come to believe that they have significant autonomy in *how* (by choosing local processes) they produce that product. The high level of conflict over standardizing manufacturing process is a product of the individuals' learned behaviors; the same individuals have little conflict over what will be produced, also because of past behavior and actions. In order for central control of manufacturing processes to succeed, the mindset of *how* things are produced must be slowly and methodically moved to the same framework as *what* things are produced.

6.2 Communication Costs

This thesis has shown that communication costs are a real and measurable part of standardization within Ford. These costs damp the improvements that standardization offers by reducing a company's ability to make changes or respond to the market quickly. The key for Ford is to develop systems and procedures that reduce communication costs and strike the balance between quick local decision making and standard processes.

One opportunity already discussed is Ford's transition to shared technical staff at one campus and how this organizational structure better aligns incentives. Other companies, such as Intel, strike this balance through less formal, but well understood, rules. For example, at Intel, once a product is no longer being as closely monitored by a corporate or development team, the local manufacturing team is able to make changes more quickly. By doing so, the requirements for communication and standardization are reduced at the end of a products life cycle. Finally, some companies, like Toyota and Honda, have a corporate culture that supports a strong central engineering function. They address the issue by making the extensive communication a part of their culture, leaving actual communication requirements intact, but avoiding the perception that increased communication is onerous.

Whatever option is selected to manage communication costs, this issue should be clearly debated and examined within Ford PTO. Ford has a long history of setting numerical

targets and working successfully to reach them. PTO can use communication costs as another metric to be systematically improved based on annual or quarterly targets.

6.3 Supply Chain Implications

We have also discussed important steps Ford has taken to modernize and improve its supply chain. Currently, Ford has accomplished the important steps of developing a common set of processes to manufacture engines and developed a machine tool vendor base to support those processes globally. Simple models of standardization have shown that flexibility improves performance of the production network. However, we have discussed the tension between these potential plant level improvements and the larger supply chain. To spread this improvement throughout in the supply chain, Ford should take the following steps:

1. **Transition the supply chain to a pull system** where possible. The change from a build to stock to a build to order model should help Ford emphasize lead time reduction and lower inventory levels. Inventory was not explicitly modeled in our analysis of a flexible supply chain, but it is certainly a major cost and quality driver. A shift to a pull system also has the potential to reduce lag because a complicated reporting mechanism to forecast production is unnecessary. Instead, engines are produced to replace those pulled downstream.
2. **Modify business processes** to support new product introduction at existing plants. A set of business processes that better matches the new capabilities of

flexible plants can reduce changeover, which is largely a function of testing the production system for a new product.

3. **Work with suppliers** to contract for flexible delivery of parts to the network of plants. Currently, even if a plant is capable of flexibly producing an additional product, various subassemblies must be rerouted from the original production site. Without a plan to manage the supply base for this eventuality, rerouting engine blocks from Kansas to Canada (for example) could be a significant stumbling block. With a more flexible system of delivery from the supply base, the network can operate with fewer constraints.

6.4 Beyond Ford Motor Company

While our analysis has been focused on Ford we have also discussed the importance of communication costs and common manufacturing processes to various companies, for example Toyota and Intel. The remainder of this subsection provides a brief summary of when these lessons might be useful in general and how we can apply any learnings.

Communication costs have the potential to apply whenever a company uses a network of facilities, processes, projects, etc that must be simultaneously controlled. The lessons of communication costs were that increasing connections in the network and requiring consensus will increase the time necessary to make changes. This applied whenever we increased the network complexity of either products or processes. We also saw that in addition to costs from the communicating more information across a broader network,

communication costs may also increase when local optima (and incentives) diverge from global optima.

Our lessons from commonality's implications for production can apply whenever a company invests in process, equipment, or designs that allow for production capacity to be flexibly matched with product demand. This investment should result in improved production (higher utilization, lower costs, etc) and improved quality as improvements at one facility can be applied to the entire network. However, this improvement generally comes at a price. This includes both the upfront investment to create a common, flexible architecture and the organizational changes required for a formerly decentralized business to operate centrally. Another key insight is that creating a network of common, flexible production systems is not enough to reap the rewards of flexible manufacturing. Our simple, generalized models and thought experiments showed that unless the overall supply chain is adapted, a flexible manufacturing strategy is unlikely to succeed.

6.5 Final Comments

In working at Ford as part of MIT's LFM partnership, I have discovered what I see as several key opportunities to continue Ford's manufacturing process improvements. I have discussed improvements that have become available as Ford shifts from local decentralized process control to a system of standardized central processes. While I have focused on the many challenges in this approach and the difficulties that I expect to arise, I also want to emphasize the hard work and success that is part of Ford. I also want to

thank the many employees at Ford whose hard work gave me an important learning experience while continuing to produce world class products every day.

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