Effective Strategies for Low Volume Vehicle Programs

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Abstract

In 2002 there were 1,314 specific vehicle models on the U.S. market, an increase of 42% in the last five years (Cobb, 2002). This trend reflects the auto industry's reaction to increased customer demand for variety among vehicle lines. In response to these demands, automakers are producing more distinct models, each in lower volumes than traditional vehicle programs. This thesis examines key strategies both in use and in development at General Motors intended to lower vehicle time to market, create exciting vehicles with lower investment needs, and produce these vehicles efficiently and cost effectively.

The use of observation techniques, interviews, and academic frameworks provided insight into the strategic and systemic issues GM is experiencing as the company executes more low volume vehicle programs. The recommendations focus on three key operational dimensions. These areas are: strategically-sound outsourcing decisions, lean manufacturing implementation, and the adaptation of GM's lean manufacturing system to the low volume vehicle program and manufacturing environments. This thesis also presents tactical recommendations in each of these areas in order to ensure successful implementation of the high-level operational recommendations.

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Chapter 1 : Introduction

Section 1.1: Thesis Background and Structure

This thesis is the result of research conducted during a six-and-one-half month period during 2002 and early 2003. This time was spent onsite at various General Motors and relevant supplier locations, most notably the Lansing Craft Centre (LCC) in Lansing, Michigan. The author used a variety of observation techniques and conducted numerous interviews to gain insight into the low volume vehicle strategy at General Motors Corporation (GM) and the success of its implementation through 2002. As a case for study, the thesis focuses on the Chevrolet SSR program and its development process and status as it transitioned to the manufacturing execution stage at the LCC. Observation techniques included membership on a team tasked with implementing lean manufacturing at the facility, attendance at program management meetings for the Chevrolet SSR, and tours of various GM and supplier plants in various stages of lean manufacturing implementation and retooling projects.

Section 1.1.1: Problem Statement

As the auto industry shifts more resources toward lower volume vehicle programs, individual companies are experimenting with different organizational structures and program management designs, looking for the most effective among the various options. Because this is a relatively new strategy and one of extreme importance to future competitiveness, automotive companies need to quickly identify the keys to success in the low volume vehicle market.

The goal of this thesis is to outline two elements critical to the full success GM seeks in the low volume vehicle market: lean, efficient operations, and efficient use of partnership and outsourcing during the vehicle development process.

Section 1.1.2: Thesis Structure

The remainder of this chapter outlines relevant background information on the auto industry and several trends that affect how automakers are evolving in order to become more competitive in the changing market. Specifically, the author presents a market sizing analysis for low volume vehicles over the next five years, which underscores the importance of effectively executing these programs. The end of the chapter introduces General Motors's competitive position and low volume vehicle programs.

Chapter 2 is dedicated to the decision to create an "extended enterprise" of distinct but closely tied companies that work together to execute large, complex projects. The outsourcing decision and its strategic implications are first generically analyzed, and then the specifics to General Motors's opportunities are explored. The chapter ends with an analysis of the tactical considerations for ultimate partnering success at GM.

The third chapter discusses lean manufacturing in the auto industry and then as it is being implemented at General Motors. An implementation model for the GM culture, based on GM's successes and struggles in the past, follows a critical look at GM's lean manufacturing system, GMS. Chapter 3 finishes with some specific keys to success that make implementing the model presented even easier.

Chapter 4 builds on the previous chapter by examining the analyzing the lean manufacturing system and determining how its implementation must differ in low volume programs. The specifics of GMS that need some additional thought for efficient implementation in a low volume environment are outlined and presented with some creative suggestions.

The final chapter recaps the major points of the thesis and outlines specific recommendations for future low volume vehicle programs at GM.

Section 1.2: The Recent Evolution of the Automotive Industry

In the past two decades, U.S. automakers have seen drastic changes in the competitive landscape from their early years. Most recently, globalization has increased competition from global players who have expanded from their own domestic markets into the American marketplace. With these new competitors come new markets for American automakers and completely new challenges. These challenges include more stringent ecological and environmental concerns, new governmental regulatory concerns, and even more price pressure as customers have more vehicles from which to choose.

In response to these new competitors, the auto industry has created numerous new structures. Now more than ever, global automakers are acquiring competitors, merging with new companies, and entering into joint ventures. The resulting dynamics have created an rapidly changing competitive environment in which some very well-established organizations are forced to adapt often and quickly in order to survive.

Fine introduces the concept of "clockspeed" to describe the pace at which an industry moves in relation to product development, manufacturing and supply chain process design, and overall business environment changes (1998). While some industries, such as information/entertainment and electronics, generally operate in a faster clockspeed environment, others, such as the automotive industry, have traditionally operated at a slower clockspeed. Changes in clockspeed, although rare, are difficult for companies due the fact that the implications of this business cadence reach far into a company's organizational structure, metrics, culture, and processes. It is precisely this clockspeed acceleration challenge to which automotive manufacturers are now responding.

Section 1.2.1: Operational Efficiency

In addition to already-prevalent competition on value and price, automotive companies are organizationally and competitively striving to respond faster to trends, causing many internal and external processes to move more quickly, all the while continuing to improve efficiency and cost. While these may seem like opposing goals, in today's competitive environment, they have become complimentary. Many operationally focused trends already in progress in the early 1990's have become critical success factors for today's environment, especially that of the Toyota-developed lean manufacturing (discussed in Chapter 3). Without the right cars and trucks to compete with the many vehicles in the marketplace, efficient manufacturing does little good. Therefore fast, efficient, and creative product development must accompany world-class manufacturing processes. In essence, in order to be both competitive on price and time to market, automakers must be able to perfect both product development and manufacturing processes.

Section 1.2.2: Low Volume Vehicle Programs

In order to compete with the growing number of competitors in the market, product portfolios have started to contain highly stylized cars and trucks that are not meant to appeal to the mass market. Instead, traditional market segments have ceased to be of sole importance, and automakers have focused on more fragmented, niche-sized consumer groups for new products. Increasingly, therefore, automakers are beginning vehicle programs with plans of only producing vehicles in limited annual volumes (5,000 – 15,000 vehicles per year, as opposed to the sometimes 100,000 vehicles per year planned volume of traditional programs).

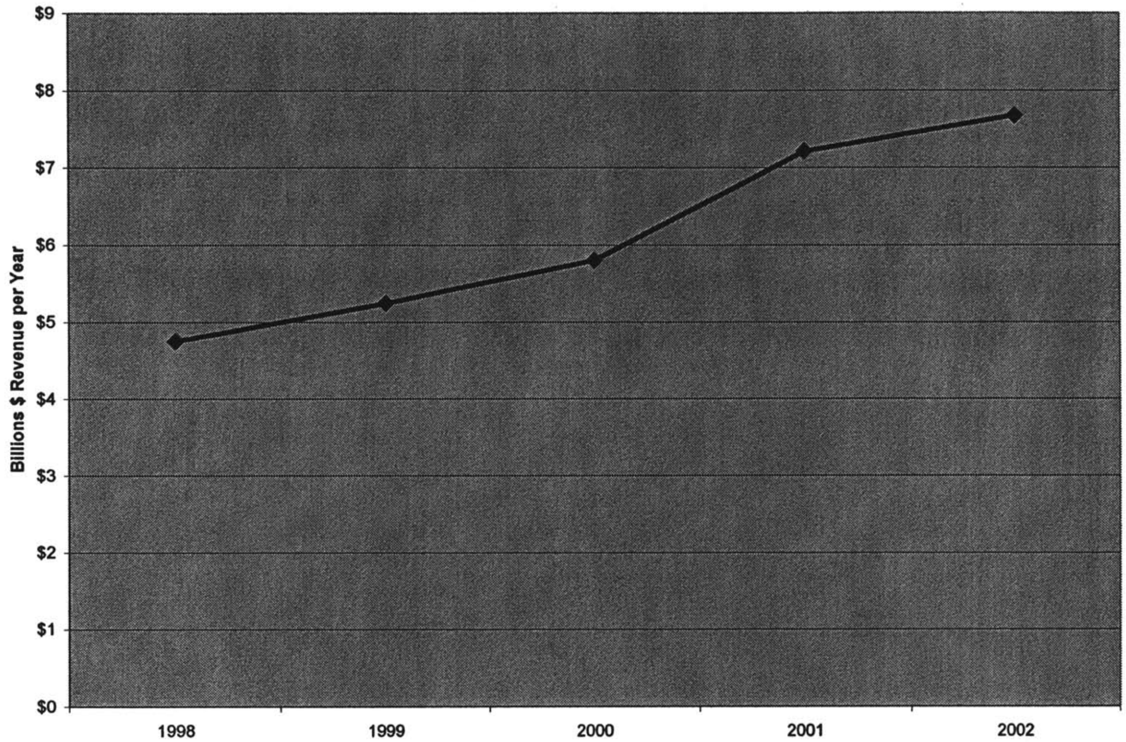

Figure 1. Low Volume (<15,000 units per year) Vehicle Revenue 1998-2002

This low-volume market, although much discussed in the automotive press, has not been definitively quantified for potential revenues. Instead of a well-defined competitive opportunity, automakers believe the low volume market to be one critical to their future competitiveness. Figure 1 shows the history of the market for vehicles produced and sold in volumes of fewer than 15,000 per year. In 2002, industry data indicates that the market is nearly $8 billion in revenue[1]. This is remarkable because although many companies have begun to execute a low volume strategy, most of the vehicles are still in the development pipeline, and are not included in the annual revenue figures yet.

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[1] This is a figure created by the author from industry data provided by the *Automotive News* data center for the year 2002.

Due to the strength of the momentum of the low volume program strategy, the market potential is important in addition to the actual revenues of the past five years. Specialty vehicles, such as these low volume products, will need to compete with the existing specialty vehicle, customization, and restoration markets that account for $25 billion per year (Cobb, 2002). Although low volume vehicles at large manufacturers may not fully eclipse the restoration market, the aim of these programs is largely the same as the specialty vehicle market – to give customers an exciting car that very few other people own. The advantage for traditional manufacturers will present itself (if done correctly) to consumers in the form of lower prices, higher quality, and more reliable resolution of warranty issues than can be expected today in small custom vehicle shops.

Knowing that most of the automakers' strategies for low volume vehicle programs have been in the development and engineering stages until mid-2003, it is easy to project that within the next two years, the low volume vehicle market will top $12 billion. In the next five years, this market should grow to a similar size as the customization market – over $20 billion, just in the United States, as automakers start to produce the many low volume vehicles in their development pipelines. Needless to say, this market will be a critical competitive instrument for any vehicle manufacturer hoping to sustain significant market share in the American market over the next decade[2].

Although producing limited numbers of certain vehicles is not a completely new concept, the current market and the increasing competition within it will demand new characteristics from these low volume vehicle programs. Traditionally, fixed costs would be spread over the large volume life of a vehicle program. Lower volume means fewer vehicles over which to spread the investments for the program. This extra cost has been passed onto the customer in the past. However, as these smaller segments attract more players and customers' price elasticity decreases, profits will no longer be made by increasing prices but by controlling costs (German, 1998).

Therefore, the characteristics of successful low volume vehicle programs are as follows:

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[2] This figure does not take into account the revenues that will be driven by overall brand image improvements caused by these exciting vehicles' presence in the marketplace.

- Designs will be more fashion-driven and address smaller fragments of traditional market segments.
- Capital expenditures unique to the specific program will be low. Lower volume leaves fewer vehicles over which to spread fixed costs. Any equipment bought will need to have a life of more than one program and be flexible enough to produce different low volume vehicles.
- For reasons similar to those above, development costs must be kept to an absolute minimum.
- Vehicles will need to move quickly from concept to showroom floor. Because designs will be more stylish, the window of opportunity in the marketplace will be shorter than traditional vehicles.
- Vehicles must be produced in an efficient and cost effective manner. Many low volume vehicles will not be priced in the highest bracket, so any inefficiency in manufacturing will squeeze already tight margins on these programs. Manufacturing waste will also cause delays getting vehicles to dealerships for anxious customers. This will damage brand image and diminish the capability to attract customers in the future, not to mention lead to lost sales on the program in question.

For automakers, time is of the essence. Already, the number of models on the market in the U.S. is skyrocketing. A *New York Times* article reported that the 2002 model year contained over 1,300 different models in the United States, an increase of more than 40% over the previous five years (Cobb, 2002).

Section 1.3: General Motors Corporation: Corporate Position and Operational Trends

Despite challenging macroeconomic times in 2002, GM set records in revenue, market share gain, and cost efficiency increases (General Motors Annual Report, 2002). Even as the competition improved, GM continued its customer-perceived quality increases, as measured by the JD Powers Initial Quality Survey by raising their ranking in "problems per 100 vehicles" (PP100) to better than the industry average on the whole[3]

[3] GM was ranked third among multi-divisional companies in the survey. Other high points for GM in this survey included the achievement of Best-In-Segment awards for vehicles in four segments and gaining on Toyota's Best-In-Class PP100 by 26% of the previous year's gap.

and narrowing the lead between GM and Toyota, the Best-In-Class producer. Additionally, GM received JD Powers accolades for their North American plant performance, earning the "gold" award for their Oshawa, Ontario plant, the "silver" award for their Bowling Green, Kentucky plant, and two "bronze" awards for a Lansing, Michigan plant and the New United Motor Manufacturing Initiative (NUMMI) plant in Fremont, California.

In addition to the quality improvements that the industry applauded, GM earned high marks in efficiency. The Harbour Report is a productivity survey that is conducted annually and serves as the definitive measure of efficiency at the manufacturing level in the auto industry. This year's study was cause for celebration at GM unlike past years when GM officials dreaded the announcement of the results. Manufacturing productivity sharply increased in 2002 for the Detroit-based automaker, and the numbers were improvement enough to top North American manufacturers. As Ron Harbour indicated in an August 2002 speech to the Institute of Industrial Engineers in Warren, Michigan, if companies are spending money in hours per vehicle, they are not able to spend it elsewhere, such as in product development innovation.

Both of these externally-measured accomplishments reflect a long-developed and patiently implemented manufacturing strategy put in motion by the former CEO and Chairman of the Board, Jack Smith. The specific focus on becoming a more lean operation that works as one global company has driven productivity progress, redundancy reductions, and quality improvements. As a result of these improvements, GM has been able to put a great deal of pressure on its competitors in the challenging global macroeconomic environment. In a drastically depressed consumer market, GM could offer widespread incentives profitably and achieve considerable market share gains. For the first time in many years, top management (specifically, Bob Lutz and Gary Cowger) kicked off the end-of-year holiday vacation with an internal communication that encouraged everyone to "celebrate (GM's success) on the run." In other words, although the fruits of much of the company's work had begun to show and were cause for celebration, there was much work to do in the coming months and years.

Section 1.4: GM's Low Volume Vehicle Programs, an Overview

In the auto industry, designers and engineers showcase their talents in the form of concept cars that are displayed at auto shows around the world. GM has a long history of producing exciting displays of cutting-edge technology on the auto show circuit. For the most part, the concept show cars serve only as marketing tools and very few make it to the showroom floor in any identifiable fashion. This is often because the cars are not designed for manufacturing, and to mass-produce these vehicles would be difficult and expensive, if not infeasible.

However, in 2000 a particular retro-inspired truck called the Chevrolet SSR inspired so much excitement when unveiled to the automotive world that GM decided to capitalize on the enthusiasm in the press and with would-be customers. That spring, the company announced publicly that they would release the SSR as a production vehicle in late 2002. This began the expansion of what is internally known as the "halo" program, which seeks to create a brand image for each division of GM's product lines by designing and selling an exciting, super-styled product to represent the spirit of the brand. The SSR would be the "halo" for Chevy trucks, as the Corvette had served as the "halo" for Chevrolet cars for decades. The SSR became "GM's icon for product innovation leadership, the company's sense of urgency and renewed commitment to exciting vehicles" (Chevrolet Communications, 2000).

The low volume vehicle strategy is not a new one at General Motors. However, there have been few examples of successful niche programs to date. For example, GM recently finished phasing out production of the EV-1, the electric vehicle produced in limited amounts primarily for the California auto market. Though some may argue that past failures are largely due to the product design of these niche vehicles, it is also true that the company's product realization process is optimized for high volume programs. Manufacturing plants contain large capital investments, large workforces, and inflexible tooling, and product development cycles are longer than fashion cycles that influence highly styled vehicles. These characteristics are not well suited for the lower volume halo programs.

However, General Motors is evolving. Product- and organization-wise, GM is well positioned to compete in the low volume vehicle market with its halo vehicles. There are several exciting products in the pipeline that have received accolades on the auto show circuit. Innovative designs keep coming, as Bob Lutz, the highly renowned "car guy" in the American auto industry, proliferates his product strategy and process at GM. Already, consumers can buy a Hummer H2 or a Cadillac XLR, other vehicles positioned in the "halo" position for GM trucks and Cadillac cars, respectively.

Section 1.5: Manufacturing Implications of Low Volume Vehicle Programs at General Motors

GM has experimented with various manufacturing strategies in order to determine how to be efficient enough in the execution of low volume programs to pursue them profitably. In order to respond to the low volume program constraints outlined in Section 1.2.2, GM has had to adjust its manufacturing processes and create new strategies within operations. However, the definition of what a manufacturing strategy entails is hazy in many employees' minds. Through interviews, the author created a list of the elements of manufacturing strategy that are relevant when considering low volume vehicle programs. These factors are listed below:

- Goals for the program that affect manufacturing, for instance part commonality and architecture similarity to other vehicles
- Percentage of GM content, or the amount that is manufactured (or assembled, in the case of complex modules of vehicles, such as instrument panels) in-house versus outsourced
- Irregular plant layouts, such as separate body shops for different vehicle architectures or no-paint-shop-layouts that can take advantage of new technologies to save capital outlay
- Whether these programs go into existing or new plants, and how they are integrated with existing products

General Motors has been researching and experimenting with different structures for each of these elements and combining them in different ways to understand the factors for successful choices in manufacturing strategy. As low volume programs become more prevalent, GM will need to find the determinants of manufacturing strategy so that optimal choices are made for each program.

Section 1.6 : The Chevrolet SSR

The Chevrolet SSR is GM's first low volume vehicle program to be executed as a halo vehicle from the concept phase through the manufacturing phase. For inspiration, GM designers looked to the heritage of the Chevy truck and combined the spirit of the Chevy heritage with modern technology. Design of the concept vehicle that launched the SSR program was very quick for auto industry standards. What would normally take a full year was brought to life in just several months.

The production vehicle retains the overall spirit of the original show car, with only two minor style-based deviations. The exterior is largely reminiscent of late 1940's and early 1950's Chevrolet pickup truck families, with updated, sleeker overall styling. The showpiece feature of the vehicle is a four-piece automatic retractable hard top that folds into a covered cavern behind the seats. Automotive critics also expressed delight that the differently sized front and rear wheels (19" and 20" respectively) have been passed along from show concept to production vehicle.

Figure 2. The Chevrolet SSR Concept Vehicle

To limit complexity, the 2003 model year SSR offers very few options to its customers. The first version of the SSR features a small block Vortec V-8 engine and comes only in rear wheel drive. Additionally, a four-speed automatic transmission is the only transmission available for the 2003 model year. The color choices are limited to four, and leather seats will be installed in every SSR. Only two real "options" will be offered, mainly allowing enhancement in the pickup bed liner. In addition, seven different accessories will be offered, including a towing package and custom floor mats.

In January of 2001, GM announced the location for the production of the SSR: the Lansing Craft Centre (LCC) in Lansing Township, MI. The choice of production facility matched the Craft Centre's excellence in limited volume, high complexity, high quality manufacturing with a product strategy for a limited production, highly styled vehicle. Production began during the late part of the fourth quarter of 2002, after regulatory concerns were resolved (The Business Journal Online, 2001) and a complete re-tooling effort necessary to transform the plant from an older manufacturing facility dedicated to making the Cadillac El Dorado to a flexible manufacturing facility for low volume vehicles.

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Chapter 2 : Core Competencies and Collaboration

This chapter outlines two interconnected concepts that have major strategic importance to General Motors as it makes changes in the way it conducts vehicle programs – industry analysis and core competencies. These academic concepts can provide strategic decision makers at GM with a framework in which to structure the problem of potential partnership with outside firms. Only with the contextual understanding of the company's position can the management at GM make the best possible decsion with respect to collaboration and outsourcing.

After presenting the framework, the chapter walks through GM's current competitive position in the industry. With this established, this chapter identifies different parts of the vehicle development process that could be outsourced and discusses the strategic and practical impacts of such decisions. The chapter ends with a guide of keys to success in the event of an outsourcing or collaborative decision, based on historical relationships within the auto industry and academic research.

Section 2.1: Outsourcing Introduction

As companies adapt to changing market conditions, they develop into more specialized producers and service providers. Because the focus on one activity often leads to a competency in this specialty over other firms, vertically integrated firms often decide to entrust pieces of their operations or products to suppliers. Often, with several expert firms involved in the manufacture and design of a product, quality is improved over the single-sourced scenario.

For this reason, the outsourcing decision has become a central part of the strategy of any firm. Cisco Systems gained great admiration for its use of contract manufacturers and its consequent low capital expenditures. Dell Computer Corporation's supply chain involves many suppliers for parts and services that allow its world-class operation. Outsourcing can pool risk across companies, improve efficiency, and provide flexibility in assets and resources.

However, making a good collaboration decision is not easy. The following sections discuss the strategic and tactical considerations that are necessary to make a well-informed outsourcing or partnering decisions. Long-term success depends on using more than economic analysis. Good decisions are so complex that some suggest that outsourcing decisions themselves may be a differentiating competitive strength for some companies (Fine and Whitney, 1996).

Section 2.2: Industry Analysis and Core Competencies

Porter, widely acknowledged as the foremost researcher in the area of modern corporate strategy, has proposed a model that provides a framework for analysis of an industry's competitive environment (Porter, 1979). This standard structure for analysis provides strategic decision makers with a set of industry competition factors to consider when making choices that can affect the long-term strategic position of the company. It should be noted that the model does not include a couple of factors that may have important impacts on such decisions, such as governmental regulation and the effects of cross-industry synergy, such as that found in the Microsoft Windows and Intel microprocessor co-design and operation. Figure 3 below shows the basic structure of Porter's framework, commonly known as the "Five Forces" model.

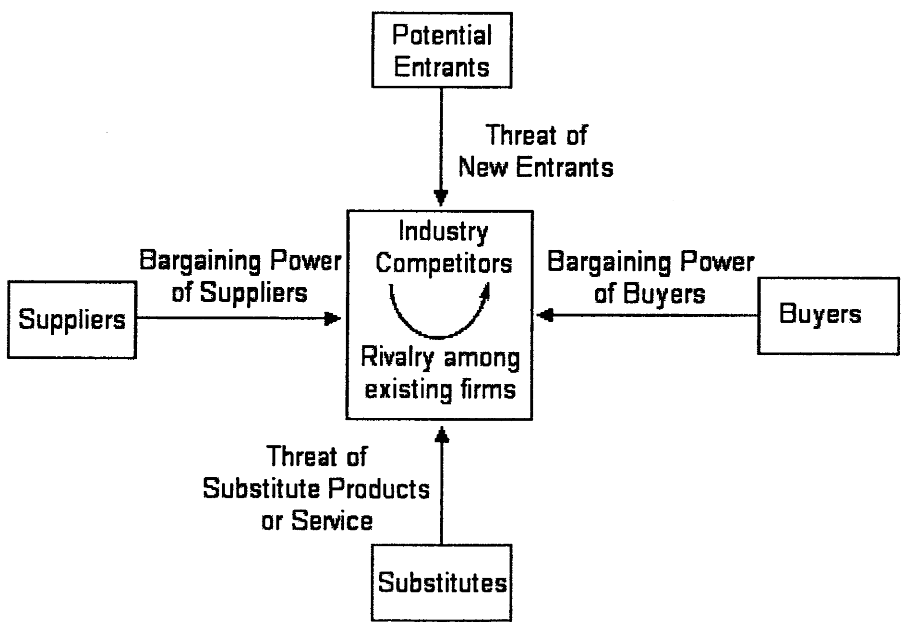

Figure 3. Michael Porter's Five Forces Model for Competitive Industry Analysis

The model provides a context for a firm's strategy by looking at the following factors:

- Industry Competitors/Rivalry – This one of the Five Forces represents the internal dynamics of the current industry players and the power struggle among the companies that compete for customers. Relevant issues include the relative sizes of the companies in the current market, the number of competitors in the industry, the growth rate of the industry, and the "exit barriers" of the industry, considerations that must be made if a company decides to stop doing business in the industry.

- Buyers – In any industry analysis, one must understand the relative power of the industry's customers because they may have an impact on the profitability of the product or service, by demanding lower prices, more service, or higher quality. Buyers are the people or firms that buy the products and services produced within this industry, and any pressure they can exert on those players within the value chain will have a profound impact on the competitors. Buyers will have more power when the industry under analysis is fragmented because they will have more choices of firms from which to buy than when the industry players are more concentrated. Likewise, if the customers are concentrated, the buyers can exert more pressure on the industry. Another factor in buyer power is the relative amount of "switching cost," or the trouble that a customer would experience if it decided to look for a new supplier of a product or service. The strength and growth of the buyers' industries are also important, because if there is little profit in the end customer's pockets, there will be less leeway for profit margins on the part of the industry under study.
- Suppliers – Suppliers of goods and services to the industry's competitors may be able to exert power on the players within that industry as well. As with the customers of the goods or services of the industry, concentration of suppliers also provides power. This power allows suppliers more control in terms of pricing and timing of the services and goods they provide and may allow them to guide the industry in terms of products, technology, or availability. Switching costs also come into play with the industry's suppliers. If it is easy to switch from supplier to supplier, each supplier will have relatively low power over the industry.
- Substitutes – If there are suitable substitutes to the goods or services within the industry under study, this will also exert pressure on the firms within that industry. Potential customers may choose to use other goods or services to fulfill

the needs that the industry players are vying to satisfy, and this will increase competitive pressures.

- Potential Entrants – Additional competition within the industry will weaken the players that are already in the marketplace. Potential entrants may be attracted to an industry if there is a great deal of profit to be made from the goods or services and if there are low requirements in terms of intellectual, tangible, or intangible capital. Entrants are limited when these so-called "barriers to entry" are high.

In his book, *Clockspeed*, Fine proposes that the sourcing decision is a key strategic opportunity in every project (Fine, 1998). In order to analyze this opportunity, it is necessary to understand "core competencies" of the organization in question. The core competency concept, a foundation of corporate strategy determination, says that companies are strategically successful when they understand the abilities in their organizations that differentiate themselves from their competition. These core competencies are the heart of the current and future competitiveness of any firm. Barney (2001) suggests using the following checklist of characteristics to determine if a particular capability is core:

- Value – In essence, a core competency must be something that adds value to the firm as a whole as it navigates the competitive landscape. This can either occur by providing a saleable asset to customers or by improving the effectiveness of the company.
- Inimitability – Core competencies are necessarily difficult to imitate, or the ability would quickly be copied by the competition and no longer be available as a differentiator to the firm who developed the skill.
- Rareness – An ability that can be classified as a core competency will be something that does not permeate the current or possible competition.
- Organization – If a rare and valuable skill exists within a firm, it will not provide realizable advantage unless the organization is set up to support and propagate that skill. For example, metrics, organizational structure, and reward systems must support following the process that provides the value to the firm.

Organizations must be careful however, not to let their core competencies become stagnant and limit their competitiveness. That is, once a company organizes itself to support its core competencies, it might be unable to adjust to changing market conditions (shifts in the power or structure as outlined in Porter's Five Forces model) quickly or effectively. In essence, the abilities that allowed success may become "core rigidities" that hinder competitiveness down the road. Therefore, as companies build competencies and follow strategies that exploit these, it is important that they keep a keen eye on the market and its dynamics to be sure that these competencies are truly beneficial. Constant reexamination of the alignment between competencies and competitive position will avoid the core rigidity problem.

Section 2.3: Outsourcing Decisions: A Strategic Perspective

As companies develop different core competencies and organize themselves around them, they develop into entities that specialize in different things, and may even move into different parts of the Five Forces model. For instance, if one firm develops its manufacturing capabilities and a competitor develops its design and engineering capabilities, they might become customer and supplier, instead of direct competitors.

Rigorous industry analysis and core competency identification are especially relevant as outsourcing decisions are made. On one hand, it is important to balance the dynamic competitive requirements that surround the project (such as increasing clockspeed and cost pressure) that drive more short-term decisions with the longer term competitive consequences of such decisions (such as core competency preservation). In essence, it is important as outsourcing decisions are made to "avoid the Intel Inside" phenomenon that IBM experienced in the 1980's (Fine 1998). IBM created an arm's-length outsourcing relationship for its operating system and microprocessor design and manufacturing in its PC products, which later became driving technologies and customer-identifiable traits for personal computers. These decisions, as IBM found, can compromise the value chain power a firm may have in the future.

So, then, how should a company make the decision to outsource parts of their process or product? Fine et al. (2002) suggest that there are several tiers of criteria that are important in making outsourcing-based decisions. Figure 4 shows the tiers of decisions that must be made by a company in order to fully analyze the strategic impact of outsourcing decisions.

Essentially, this framework asks the strategic decision maker to think carefully about the particular part or process step that they are considering for outsourcing in a systematic fashion. Several aspects of this "outsourcing element" (Fine et al., 2002) and the competitive environment are critical factors in making the sourcing decision.

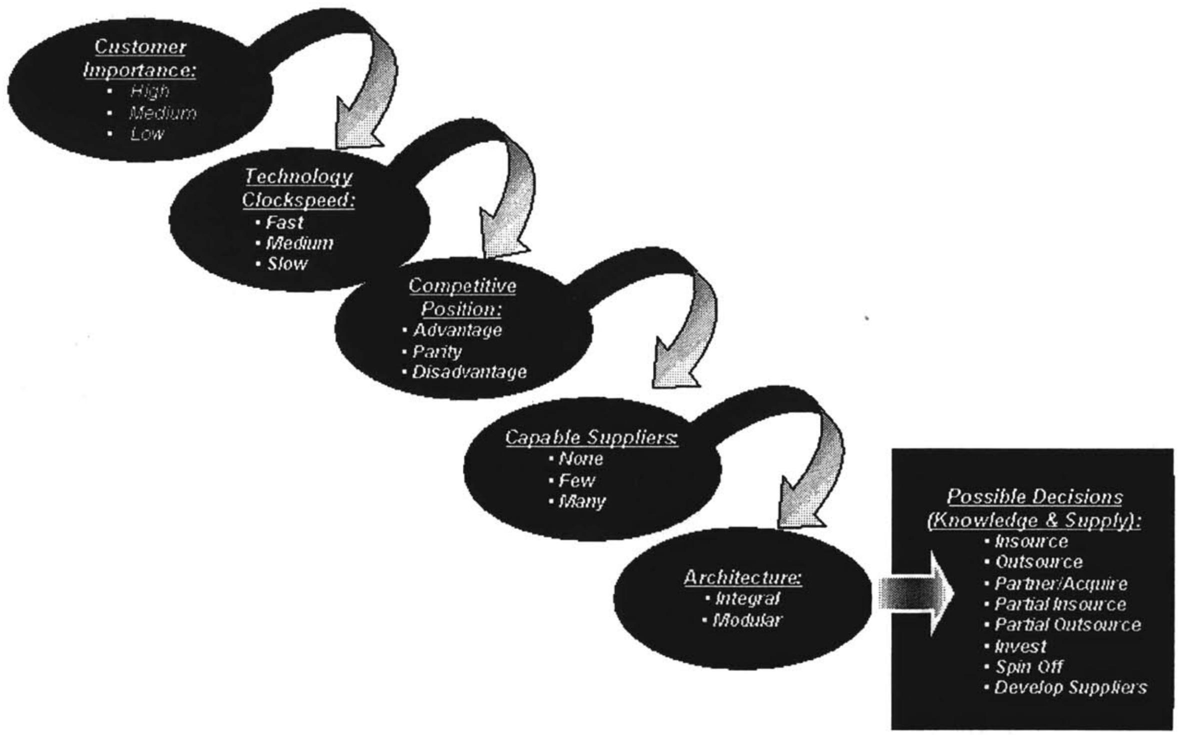

Figure 4. Analysis Tiers for Strategic Outsourcing Decisions (Fine et al., 2002)

The first levels of consideration are highly strategic in nature and require that someone in a high-level and cross-functional position be involved in decision-making. The initial level relates to the potentially outsourced element's importance to the customer. If it is a customer-critical part or process, outsourcing control of this element may pose a risk to the company's ability to satisfy their customers. Outsourcing may not be the wrong strategic decision in all cases, even for very important elements, but it will be necessary to implement extra control mechanisms and management for the outsourcing process.

Technology clockspeed refers to the pace at which the underlying technology of the part, process, or product evolves. In a faster clockspeed environment, competitive advantage may be gained and lost very quickly, causing even a short-term decision to have long-term effects. On the other hand, if the industry moves at a slower velocity, the outsourcing decision on any one element for any one period may have less potential lasting strategic impact. Overall, it is important for strategic decision-makers to understand the clockspeed and criticality that frames the outsourcing decision before more practical factors are allowed to play into the selection of outsourcing strategy.

The next level of consideration in the sourcing decision examines the competitive position that the company currently maintains with respect to the outsourcing element. While this may not be as important as the aforementioned strategic considerations, the company's ability to produce or execute the element relative to the rest of the competitors in the market space may serve as a tiebreaker in the outsourcing decision. In essence, if a company is concerned about the strategic or competitive nature of the element but the internal capability to produce or execute that element is either on par with or less than that of the suppliers available or its competitors, the company may decide to outsource the element[4].

If the element is something that the company would consider outsourcing, it then must inquire about the capabilities of the possible suppliers for the product or process. If there are no outside firms that will be able to adequately provide the element, there is clearly a high barrier to the success of outsourcing. However, if there are many suppliers for this element, this might be an indicator that it is a heavily outsourced element in the industry and therefore may not be considered a core strategic advantage for many of the company's competitors. This does not dictate that the element should necessarily be outsourced, but it can give a competitive context in which to make the decision.

Finally, it will be important to look at the architecture of the product or process. If the final product is largely one system with many integral parts that work together, it will be more difficult to successfully outsource the elements of that system because of the complexity of the coordination and understanding necessary to be part of the system. If a product or process is designed in a more modular fashion, where commodity-type parts or services are designed with common interface and are subsequently pieced together to

[4] Although many American companies decide to outsource what they are not comparatively good at, there is an alternate philosophy, often found in Japanese companies. This philosophy dictates that the company should insource those things that may be construed as strategic advantages as away to build these capabilities inside the company (Fine and Whitney, 1996).

create the whole, outsourcing will require fewer complex interactions and will have less risk of quality and integration functionality issues.

After these considerations, the type of outsourcing relationship should be examined. Even if there is some strategic risk in outsourcing a part or process to an outside firm, there are ways to reap the benefits of increased resources or external skill sets that outside collaboration can provide. To do this, the company should establish a formal relationship that will allow them to achieve their outsourcing goals without fully compromising their strategic advantages in their industry or giving up their competitive position. Relationships like these include joint ventures, equity partnerships, and acquisitions.

Where much of the academic research stops is how to manage the relationships put into place for these very delicate and important decisions. This topic will be covered later in this chapter, with a practical focus on GM's options.

Section 2.4: General Motors: Competitive Analysis and Core Competencies

A Five Forces analysis of the auto industry as it has evolved over the last several years can be found in Figure 5.

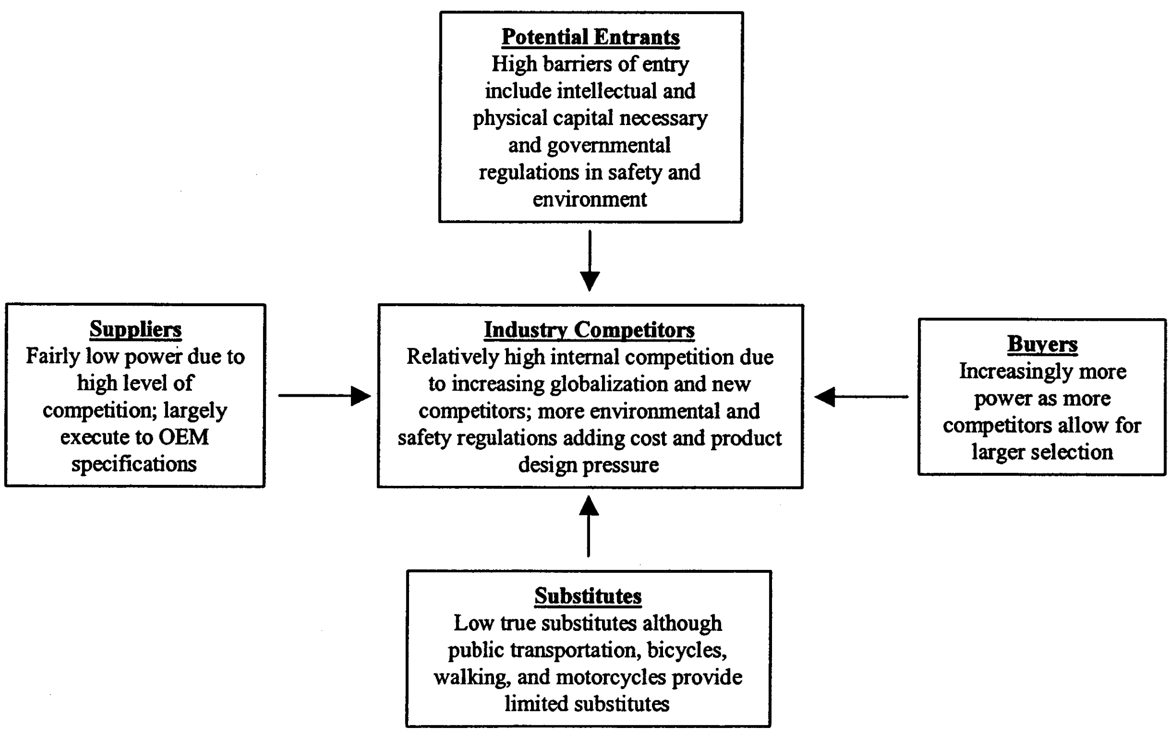

Figure 5. Current Automotive Industry Five Forces Analysis

At a high level, General Motors's competitive success depends on its ability to efficiently but completely manage the complex product development, manufacturing, and distribution systems that its vehicle programs demand[5]. This process requires a tremendous amount of intellectual and physical capital infrastructure. The ingrained knowledge and monetary requirements currently in place create very high barriers to entry in the automotive business. Suppliers have some input into these processes, but the main strength in the value chain lies with the automaker. Customers' strength has been increasing, but given that the customers are not concentrated, their relative power in the chain is fairly low. The only power they can exert is individual, as a customer can switch between brands of vehicles on each purchase.

GM is currently trying to find the balance between the short-term dynamics that place cost and time pressure on vehicle programs and future competitiveness. In the case of low volume vehicle programs (which tend to have shorter lifecycles and more fashion-oriented designs), the time and cost pressure is even more intense. The strategy to create more vehicle models also increases the workload for the engineering-related staff. With the increased pressure on vehicle programs with more competition for internal resources, dependence on suppliers has increased (Fujimoto, 1999). Consequently, the outsourcing options become even more central to program design.

Section 2.5: Outsourcing and Low Volume Vehicle Programs

This section walks through the different levels of decisions to be made by a company when it has decided to outsource some or all of a vehicle program. These considerations will only be important if the company has already considered the strategic impact of the outsourcing decision, as outlined in Section 2.2. The three levels of decisions to be made in the event that partnering or outsourcing is the correct strategy are: what to outsource (partially driven by the strategic implications mentioned above), to whom to outsource, and how to manage that relationship.

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[5] This is, of course, only part of the total formula for success. GM must also design exciting cars that customers want, but the management of the program process in a cost-effective and timely manner is absolutely critical to the fruition of these designs.

Section 2.5.1: What Can Be Outsourced: Outsourcing Elements

With such an accelerated design and engineering schedule for the halo vehicles GM is facing an incredible opportunity for the company to partner with suppliers of several products and services. This section will outline several elements that are theoretical targets for outsourcing (based on the research and understanding of the product development process of low volume vehicles of the author, not on actual situations or models in use at General Motors).

In the case of halo vehicles, the process essentially begins with the concept vehicles that are shown to the public and press at the auto shows. At this point, many automakers utilize the design talents of outside design firms. These firms may provide concept drawings, vehicle mock-ups (three-dimensional models), and/or specific parts or whole systems for the show vehicle. Essentially, a partner company may be involved in every aspect of the concept stage of the vehicle.

Although the show cars are functional, they are far from being fully designed and engineered. Safety and reliability are essentially ignored in the concept phase but become important for vehicles that will be put out onto the roads. The ability to produce the vehicles in volume is also de-emphasized for show vehicles. For instance, engineers must determine how to make parts that have the same stylish appearance as the show cars but can be produced in materials that provide consumer-desired durability. Many concept cars have deeply curved styling, but they are usually made out of composite material or aluminum, which are both difficult to form in mass production or are cost-prohibitive for the production version. Steel, the main metal component of mass-produced auto body panels, has physical limits with respect to the amount of depth it can handle in curve-styled parts. Therefore, the engineering and design phase has many complex materials and structural issues to solve. During the engineering and design phase, styling is refined, systems and modules are engineered in detail, and parts from other vehicles are integrated where possible. This complex design refining and engineering has great potential for partial outsourcing or partnership.

Another piece of the pre-production process concerns the sourcing for the each of parts of the vehicle. The coordination and resource need for this process is immense. Coordination between the developing designs, many different suppliers' technology roadmaps, and program specifications, such as the volume of the parts needed and their delivery specifications, is an extremely complex task. Many of the sub-processes in this sourcing portion of the program iterate many times as vehicle designs evolve. The potential supplier base is large and diverse, and coordinating several iterations of supplier quotes, specifications, and purchase orders is a large task. Outsourcing the coordination of sourcing and the running the purchasing functions to support the manufacturing process is another opportunity to increase effectiveness of low volume vehicle programs.

Part of the design process includes the decision of how to manufacture parts or assemble the vehicles when they go into production. Assembly or forming technologies are applied to find the most efficient method of producing the vehicles in low volume programs. During the execution phase (manufacturing), there are several options for outsourcing, including the procurement activities mentioned above, full outsourced manufacturing, or sub-system or module manufacturing, in which a major supplier acts as an integrator of other parts and then ships sequenced kits (to coincide with the production schedule) or whole vehicle sub-systems (such as an integrated instrument panel, or dashboard) to the OEM's manufacturing facility. All of these models exist today, some even in larger volume production, but successful leverage of the right models in low volume programs will be another key to success.

Different programs will have certain elements that lend themselves to outsourcing. In a program where time is especially sensitive, more elements may be outsourced or take on partners. If creativity or "out of the box" thinking is required, design ideas may come from an outside firm. If many new parts are required, the sourcing and procurement functions are opportunities for outsourcing.

At GM and other automakers, all of the elements outlined in this section have either been partially or fully outsourced or have involved partners in their completion. As new low volume programs progress through the vehicle development process, these companies are looking to outside firms for more value-added services and larger parts of their vehicles. Consequently, more suppliers are offering an expanded selection of services.

Section 2.5.2: The Next Outsourcing Decision: To Whom

The auto industry extends beyond the limits of the OEM automakers to product and service providers. Marketing, legal services, designers, contract manufacturers, and multi-tier suppliers can all be contracted for hire by OEMs during different phases of a vehicle program. Each of the previous outsourcing elements is readily available from outside suppliers.

In deciding to whom different elements should be outsourced, the relative skill sets of the available suppliers are key considerations. Many of the outsourcing elements for vehicle programs have proficient suppliers outside of the OEMs. For instance, there are many design firms that have been working with automakers for concept cars and show vehicles for a long time. Additionally, suppliers of automotive parts have been migrating toward positions as module suppliers or parts integrators of larger auto systems. Again, the availability of external skills should be balanced with the strategic considerations of Section 2.2.

Section 2.5.3: Once the Decision is Made: How to Manage Outsourcing

As low volume vehicle programs become more prevalent and outsourcing more common, management becomes paramount in importance. In a sense, the lines between firms become blurred, essentially creating "extended enterprises" to bring vehicle programs to fruition. Once partners are selected and elements for outsourcing are chosen, the hardest part of the outsourcing decision becomes the focus – how to manage the relationship. There are two major types of management decisions that are critical: what type of relationship should be set up and how to manage the interactions of the multiple firms that fulfill the program's requirements.

In the strategic portion of the outsourcing decision, the final level of consideration was the type of relationship that is appropriate for the element or program (see Section 2.2). Although the set of options available is something to consider in the strategic portion, after the decision is made it becomes of practical and tactical importance. The type of relationship also dictates many of the considerations necessary in the management of the extended enterprise. History has shown the impact of the type or relationship in an outsourcing or partnership arrangement. Many companies have gained or lost value chain power by outsourcing components or services and creating a non-optimal relationship with suppliers. The "Intel Inside" dilemma mentioned previously illustrates this point. Had IBM chosen to retain their equity share in Microsoft and Intel, as they had early in their relationships (Fine, 1998), the success in these supplied parts would have had a neutral impact on IBM. Because they instead chose to manage it as an arm's length relationship, all of the benefits of these technologies' successes have gone to Microsoft and Intel.

Many different options are available to a firm as it creates its extended enterprise. Choosing the right one for the situation is tricky but critical. Several factors help to dictate the best choice for the relationship. Strategic importance of the outsourced element and the level of commitment needed long-term are the major considerations. For instance, joint ventures can be structured to distribute benefit equally among firms, encouraging each partner to engage fully and long term. Arm's length structures make more sense when the products or services are more commodity-like. Exchanges of equity can mitigate strategic risks when important pieces of the process are outsourced.

Another consideration in the decision for the relationship structure is the amount of interaction that the automaker wants to or can afford to have. This may be constrained by resources, causing the outsourcing to be chosen to speed up the timeline or avoid adding permanent resources for the program. However, there may be some benefit to having a great deal of interaction in the relationship. Having a new perspective on a process or exposure to new technologies may create organizational learning in the automaker's organization if it is an active part of the process. In other words, choosing a structure that is cooperative and inclusive is an opportunity for both firms to learn from each other and may lead to enough learning on the part of the automaker that it will not need to outsource the element in the future.

Once the type of relationship is chosen, management structure and processes must be created to maintain the relationship and drive the project effectively. Coordination requirements increase in the extended enterprise. In the case of outsourcing elements of an automotive program, the OEM must act as the integrator of the internally and externally executed parts of the program. Therefore, the OEM has a large stake in the program's management, even if the bulk of the program is outsourced. The implications of this vital role are important to the OEM, and it should not overlook the resources that will be necessary to fill this role.

Section 2.6: The Strategic Impact of Outsourcing at General Motors

General Motors needs to consider the same strategic issues as have been outlined in the previous sections. First, the high level management of the company needs to understand the objectives of the program and how they fit with the overall goals of the company and then balance the constraints of the program with the strategic outsourcing considerations.

Clearly, outsourcing places more importance on the relationship between GM and its suppliers. Relationships can no longer be easily created and severed based solely on low prices or short-term service performance. The increased complexity of the services and parts provided by the supplier base moves away from a commodity-driven supplier relationship that allows easy replacement of suppliers. Instead, there is a "lock-in" effect created in the relationship between supplier and customer.

Outsourcing and partnering also shifts the power in the value chain a bit toward the suppliers. Figure 6 shows the power shifts in the value chain that are occurring as a result of low volume vehicle programs in which outsourcing is used. This figure shows values in relation to the "current state" Five Forces model in Figure 5.

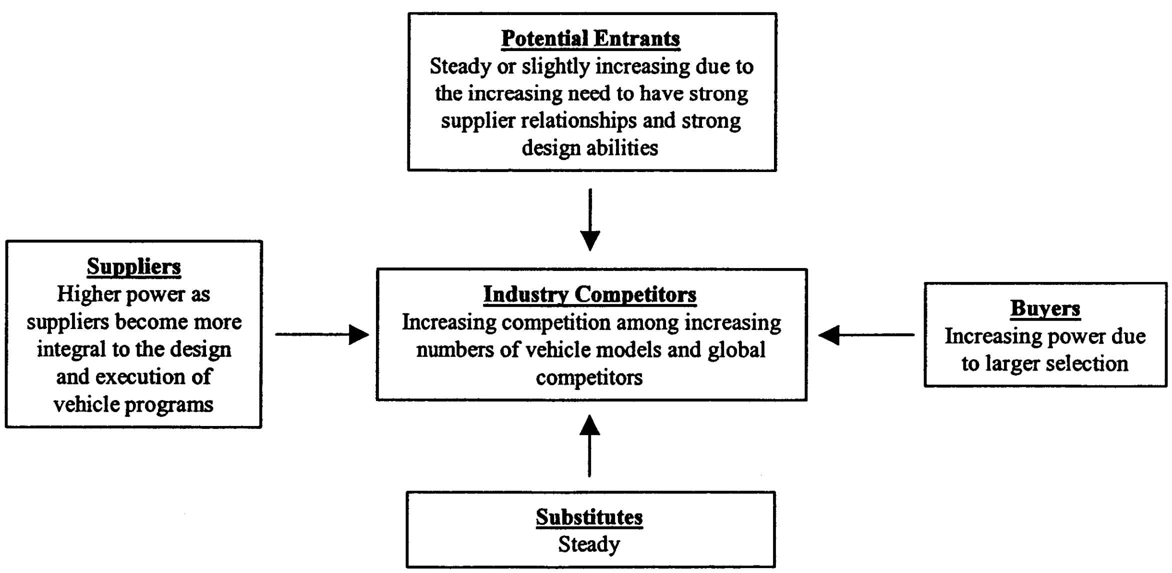

Figure 6. Shifts in Five Forces Model with Outsourcing

What is evident in this figure is that using outsourcing or partnering for low volume programs changes the power balance in the auto industry. Buyers start to have more power not because they are more concentrated and demand more attention individually, but because there are a growing number of products from which they may choose. These vehicles are coming from increased competitive forces within the industry as global competitors move into new markets. Therefore, there is more internal competition. The outsourcing decisions are shifting more power to the suppliers as they provide more complex pieces of the design process and automobile. There is some amount of lock-in as GM entrusts more value-added elements to outside firms. This lock-in creates more interdependence and therefore more power in the relationship on the side of suppliers.

One other strategic, long-term consideration for GM is the degree to which the company wants to learn the process or understand the parts that it is outsourcing. If the element is common to many low volume programs and the strategic direction continues toward more low volume programs, it might make sense to keep the element inside the company or at least make sure that the relationship structure chosen for outsourcing that element is one of inclusion. As mentioned before, this will require resource expenditures. If this is a constraint for the particular program and those in the future, outsourcing makes sense. However, the dependence on the suppliers will be stronger and longer term, as the extended enterprise becomes more important to GM.

In essence, the initial strategic decisions about outsourcing in low volume programs at General Motors must be made by a high level of management in the organization. The decision must balance the constraints of the particular program in question with the long-term strategic direction of the company. While sharing risk and minimizing investment in the short-term, the arrangement must take into account the future strategic costs and potential learning that might be lost. Finally, coordination costs cannot be ignored when the decision to outsource is made. Outsourcing does not completely relieve GM of an obligation to be a part of whatever elements it uses external sources for, so these coordination costs must be a part of the decision as well.

Section 2.7: The Tactical Considerations of Outsourcing Low Volume Program Elements

This section outlines the opportunities for outsourcing elements in the low volume vehicle programs at General Motors, based on the observations throughout the Chevrolet SSR program. Because there are many suppliers in the marketplace and GM has a better understanding of their abilities than the author was able to discern over the short time at the company, there is not much in-depth discussion on the specifics of the decision as to whom the elements should be outsourced. Instead, the section includes specific management and coordination suggestions based on the limited exposure the author had to current suppliers to General Motors.

Section 2.7.1: Outsourcing Elements: Opportunities for GM's Low Volume Programs

All of the elements outlined in Section 2.4.1 are opportunities at GM for outsourcing or partnering in low volume vehicle programs. Concept creation, design, engineering, parts manufacturing, and sourcing and procurement functions can all be outsourced or executed with strategic partners. However, in the time-pressure, low cost environment of the low volume program, many of these functions must be done in parallel – and very efficiently.

Concept cars often utilize partner design firms. In the case of low volume programs, the concept phase is an opportunity to start thinking through the subsequent processes that will occur if the concept is successful. As the concept is introduced to the auto world, preliminary feasibility studies for production should be underway. In this study, production options and sourcing options are important to understand before making a commitment to production schedules and program budgets. Partnering for these early phases will accelerate the timelines further into the program.

The specifics of the program will dictate the best opportunities to take advantage of outsourcing and partnering options. For most programs, however, time will be limited in order to take advantage of the current fashion trends. Therefore, without an additional expenditure on full-time engineers and designers, most programs will require some arrangements with outside firms.

Section 2.7.2: Management Concerns for GM's Low Volume Outsourcing

In order to achieve most of the goals of low volume programs, partnering or outsourcing will be key. Although the decision of what to outsource and to whom is important, the execution of the program with the newly created extended enterprise will command a great deal more time and attention. Based on supplier interactions observed by the author, the following points are essentials for successful coordination of the extended enterprise in time-pressured, resource constrained low volume programs.

First and foremost, GM needs to exploit its core competency and ensure that this strength of complex program management is taken advantage of, even when partners are executing the tasks of the program. Although there is some value to having an outside perspective on the program management technique to expose inefficiencies or ways to improve or move more quickly, to cast aside the main strength of the company is a grave mistake. To this end, the first point of this section is that it is imperative that a common project management doctrine be adopted by all of the members of the extended enterprise. This doctrine needs to include timing for deliverables and the creation of a common set of expectations, even if the deliverables are not necessary inputs to cross-company processes. For example, if GM expects a supplier company to have done enough due diligence in its process by a certain date, creating a deliverable that GM would normally have, that must be a part of the project plan. In essence, all expected deliverables must be in this plan, regardless of whether they are expectations for use in other processes internal to or external to producing organization.

Related to the deliverables, the next management imperative is a clear scope of responsibility for each of the organizations in the extended enterprise. Vague descriptions, such as a contract to perform the procurement and sourcing functions, will cause rework, duplication of activities, and inefficient hassles in the program. In the case of outsourcing the procurement activities, many more detailed guidelines are necessary. For instance, which parts will the supplier be responsible for during the program (all of them, the ones that are not common to any other GM vehicles, or the parts that will be delivered to GM's facility (as opposed to those going to suppliers' facilities)) must be clearly defined. These details must be decided from the outset, so that the proper resources and time can be allocated by the appropriate organizations. It will also serve to nurture the relationship of the companies in the extended enterprise rather than allow for conflicts due to misunderstanding.

As with any project, the proper metrics must accompany the project plan. This is especially important in the cross-company situation created by complex outsourcing relationships. Quality expectations for deliverables should be part of the original plan. Success metrics for the program must be decided at a project level, and each company involved must make sure that their internal metrics are in-line with the program-level metrics and goals.

Finally, in order to create a seamless flow throughout the project, teams from all aspects of the partnership should be involved from the beginning of the program. Most notably, any manufacturing organizations must be involved in the design and engineering portions of the project, at least to be able to offer manufacturing perspective to design. Additionally, first-hand involvement upstream will allow for realistic preparations for the downstream processes.

Section 2.8: Chapter Summary

This chapter outlines the full scope of considerations in outsourcing and partnering decisions in low volume vehicle programs. The strategic considerations first dictate that GM must understand its core competencies so that they are incorporated into the extended enterprise. Next, high-level management must make some preliminary decisions from an integrative, cross-functional perspective to understand what elements of the program might be outsourced and under what relationship structures. At this strategic level, management must understand how outsourcing and partnering decisions balance the shorter-term constraints and goals of the specific program as well as the long-term corporate strategy implications of involving others in the program management process. Then GM can consider the tactical aspects, from what to outsource, to whom, and then finally, how to manage the outsourcing relationship.

Outsourcing and partnering will be a critical part of success in the low volume vehicle programs of the future. However, to realize the benefit of the extended enterprise approach, the right strategy and management must accompany the arrangement.

Chapter 3 : Lean Manufacturing

Outsourcing is only one skill that General Motors will need to perfect as it introduces more low volume programs. Not only must the program get vehicles to the marketplace quickly, but they must also be produced in a cost effective fashion. As in the program development, there will be little room for error or waste in the production process because of the lower number of vehicles per annum over which costs will be spread.

This chapter focuses on the production system known as "lean manufacturing," the accepted standard for best practice operations worldwide. Following this introduction, the chapter describes GM's Global Manufacturing System (GMS), the company's internal standard intended to capture the essence of lean manufacturing for worldwide implementation. Finally, the chapter discusses the implementation of GMS in brownfield environments, with special emphasis on the lessons learned throughout the world as GMS has permeated manufacturing facilities.

Section 3.1: Lean Manufacturing: An Introduction

In most manufacturing-based industries, "lean" has been a buzzword synonymous with world-class competitive operations for over two decades. While there are many interpretations of the word and even more ways that the lean mindset has been implemented in these companies, there is one over-arching concept that is the focus of lean: the continual seeking out and elimination of waste in the system. This waste may surface in several forms and in all areas of a process or organization. The goal of lean thinking is to expose the wasteful situation and drive the waste out of the system. Most companies' lean manufacturing systems focus on the implementation of Just-in-Time (JIT) manufacturing and materials systems, *kanban* materials management tools, and quality control procedures, all of which are countermeasures to waste in manufacturing environments.

The Toyota Production System (TPS) has been the basis for the movement toward lean manufacturing and lean thinking. This widely admired system for operational excellence not only encompasses shop floor manufacturing techniques but also sets parameters for product design and supplier relationships. Because of Toyota's competitive success throughout the 1970's and 1980's, times that were particularly challenging for American automakers, TPS has been widely studied and copied. However, Toyota's system still provides the company with a competitive advantage (Fujimoto, 1999).

In order to explain how, even after years of TPS benchmarking, Toyota's advantage remains, Fujimoto suggests that there are three levels of manufacturing capability (Fujimoto, 1999). These levels are the following:

- Routinized manufacturing capability. Capabilities such as production control procedures and material replenishment policies represent this level. These are the static and routine processes that a company uses to run the operations of the facility. These processes are optimized for a stable environment and are most easily learned and copied by other facilities or companies that do extensive benchmarking.
- Routinized learning capability. Commonly recognized examples of this type of organizational capability include continuous improvement processes and problem solving methodologies. This level of the capability structure is more dynamic because it has to react to different learning opportunities but is still highly routine.
- Evolutionary learning capability. This capability has developed in some companies' cultures to be dynamic and make decisions in unforeseen or completely new circumstances. It is inherently non-routine and reflects a culture that has developed insight and the ability to adapt.

The first two levels of Toyota's manufacturing capability have been highly studied and documented. From these studies have come specific TPS-based manufacturing systems for most manufacturing companies, including Kodak's Kodak Operating System, Ford's Ford Production System, and General Motors's Global Manufacturing System. Each of these systems is a set of philosophies, tools, standards, and values based on the first two levels of manufacturing capability displayed at Toyota in the 1980's and captured in the book *The Machine That Changed The World* (Womack, Jones, and Roos, 1991).

What has not been adequately captured and implemented in most documented cases is the deepest level of learning – evolutionary learning capability. This is the heart of the culture at Toyota that creates a "company of scientists" (Spear and Bowen, 1999) and has sustained Toyota's success. This culture is one that is focused on the continuous elimination of waste, and every employee is an empowered and creative asset in that mission. While the tools documented are part of this mindset and provide glimpses into the methods that Toyota uses to counteract waste, these are not the real key to the long-term success.

Creation of this kid of culture is very difficult for organizations, but crucial. The next sections will discuss the specific lean manufacturing system that is standard at General Motors and a model for implementing this model and creating the culture of continuous waste elimination.

Section 3.2: The General Motors Global Manufacturing System

GM's Global Manufacturing System (GMS) has evolved into the standard for how General Motors manufactures vehicles worldwide. The system has developed over the last decade as GM tried to implement lean manufacturing concepts throughout its plants and as the company learned from its joint venture with Toyota at the New United Motor Manufacturing Initiative (NUMMI). After many unsuccessful attempts at implementing pieces of the TPS toolset within its many manufacturing facilities, top manufacturing leadership gathered to discuss best practices throughout their worldwide manufacturing network. The outcome of this gathering was what would become known as GMS.

GMS consists of a single, worldwide vision and a set of cultural and business-based priorities. These priorities are well-linked to the vision of the company, "to be the world leader in transportation products and related services. We will earn our customer's enthusiasm through continuous improvement driven by the integrity, teamwork, and innovation of GM people." Supporting this corporate vision are GM's Core Values:

- Integrity
- Customer Enthusiasm (internal and external)
    - Internal customers are enthusiastic when they are involved, empowered, and given opportunities to develop both personally and professionally.
    - External customers must have a good buying experience (sales, marketing, distribution + availability/lead time) and a good ownership (durability, reliability) experience.

- Continuous Improvement
- Teamwork
- Innovation
- Individual Respect and Responsibility

Respecting this vision and the core values of the corporation, GMS lays out common goals and principles for its worldwide operations. The goals and principles of GMS do not supercede or conflict with the corporate directions, but provide a manufacturing-based level of detail. In fact, the core values relate directly to the corporation's metric system that has been created to ensure that the company adheres to the core values and vision. The GMS principles are the foundation on which the next several layers of the system are based. They are: People Involvement, Standardization, Built-In Quality, Continuous Improvement, and Short Lead Time. Each principle is interrelated with the others and is part of a total system. In essence, no one principle is a stand-alone solution to waste. However, GMS's focus is the operator-level employee on the manufacturing line. All others in the plant are to support the operator as he or she builds quality vehicles. This is a shift away from the top-down management style of traditional automotive plants, where operators were treated as manual labor as opposed to intellectual parts of the system.

Within each of these principles are several "elements," or tools that guide those implementing and running under GMS to achieve the goals in each of these areas. One would find easily recognizable TPS tools such as standardized work, *kanban* (material management technique) and *andon* (signaling mechanisms for line workers to communicate they need assistance) systems, and management by *takt* time (controlling the speed of the manufacturing line based on customer demand) at the element level. Although the elements are interrelated, like the principles, a practical GMS implementation often prioritizes a few above the rest depending on the program and manufacturing facility that is going through the change.

Additionally, GMS implementation at GM is aided by a formalized training program that occurs in one of two ways for each manufacturing facility. In order to understand this, some background on the organizational structure around GMS is necessary. After the creation of GMS, a centralized engineering organization now called the GMS

Implementation Center formed to act as a depot for GMS information – from training materials and standards to best practices and lessons learned from GMS implementations. Many of the people in this organization have spent time at NUMMI and been involved in greenfield lean startup operations in Europe. In essence, the GMS Implementation Center is the group of lean manufacturing experts.

The GMS Implementation Center owns the training materials for the system. Overview classes as well as detailed training sessions occur throughout the world and are executed by GM's training organization, known as GMU (or General Motors University). In fact, for most GM employees, some level of GMS training is required each year in their individual development plan. While this is the more common method for training, it is not the only model.

When a plant, such as the Lansing Craft Centre (LCC), wants to undertake a large-scale GMS implementation, it can utilize more than just the training information from the GMS Implementation Center. In such a case, a small team of lean experts temporarily move to the plant's location and act as guides through the change process. At LCC, the former industrial engineering group at the plant, who ran the project management and engaged the top plant leadership, owned the lean implementation. The on-site GMS Implementation Center team helped guide the process, ensuring that the plant's team covered all of the necessary steps, engaging outside resources when beneficial, and "training the trainers" in GMS.

As an additional aid to propagate and help implement the GMS principles and elements around the world, GM has created what they call core requirements, which act as the basis of an auditing tool as plants are assessed for GMS compliance. These requirements are numerous, and provide auditors a checklist with which to evaluate every General Motors manufacturing facility around the world.

Section 3.3: The Implications of Standards

The compliance measures and core requirements are meant to be the standard by which GM measures a successful GMS implementation. However, standards can be a double-edged sword in many organizations.

Standards can undoubtedly be beneficial. In fact, standardization is a key element to GMS and all other lean manufacturing systems. "Getting common," as GM calls the process, can help in two major ways: quick proliferation of current best practices and more effective maintenance of equipment and processes. The former aids most in rapid growth or highly competitive periods, as velocity of benefit realization due to improvement by utilization of best practices can make the difference in competitive position in the market. The latter benefit is relevant in sustaining machine uptime and operational efficiency.

After identifying best practices in an organization, quick and effective proliferation of these ideas throughout a large, geographically diverse organization is possible only after these processes and/or equipment are documented. These standards become the basis for equipment purchasing, training, and process standardization in the different locations. This concept was popularized by Intel's "Copy Exactly" philosophy that allowed the company to expand their capacity rapidly during its growth period in such a way that allowed ingrained organizational knowledge to permeate its operations, regardless of geographical location.

Especially in the case of equipment, such as conveyors or assembly robots, companies with more than one manufacturing location benefit by standardization in terms of their abilities of centralized engineering functions (or other plants' engineering organizations) to aid in resolution of issues. Common equipment creates a larger base of knowledge, as more plants implement the standard machines and learn about their operation and maintenance. Complex problem resolution is also more easily achieved with a larger experience base.

Despite these benefits, standardization may also have some adverse effects, even when used effectively to achieve the results mentioned above. These include the lessened ability to make autonomous and quick improvements at a plant level and the loss of customization ability at a product or geographical level. Not all products and processes lend themselves to the same constraints or efficiencies. Take, for example, the low volume vehicle programs, where capital investment must be kept to an absolute minimum. Following the established standards for machine equipment, while it might make maintenance easier, may also cause overspending for the manufacturing facility and result in unprofitable programs. Although complications such as these will be outlined in Chapter 4, the subject warrants mention here.

Section 3.4: Some Comments on GMS

GM's GMS is a comprehensive, systematic lean toolset for manufacturing at a large company like GM. It is an excellent aid for unifying operations across geographies and taking advantage of the ingrained knowledge of the diverse and experienced organization. GMS implementation has also been a large part of the recent success in the Harbour Report and JD Powers Initial Quality Survey, and there are many more benefits to come as manufacturing operations adopt more and more of the GMS elements and begin to build a culture of lean thinking.

Support for GMS is evident on all levels of the organization. High-level managers are trained in the basics, and they understand the extent to which GMS has been a part of the company's recent successes. Middle management with experience at NUMMI or other showcase facilities are true believers in the power of lean manufacturing. Lower level engineers and supervisors with exposure to GMS are excited about its proliferation throughout the company. Even at the operator level, where it counts the most, the general reaction is delight with the support given to those who do the work on the manufacturing floor. The picture is not all rosy, however. Those without first-hand exposure to lean manufacturing still lack much of the understanding of how instrumental and radical this change is for GM. These people exist throughout the manufacturing organization, as well as in functions that support manufacturing. Although these employees without direct knowledge of lean are not wholly resisting GMS implementation, they will not have full faith in the system until they have the chance to work in the lean environment and understand its benefits.

One criticism of the system is that it focuses on teaching and measuring the routinized capabilities of TPS, and does not, to a large extent, try to capture the evolutionary aspects of lean. Instead of standardizing how to change the culture, GMS standardizes the vocabulary and toolset that is used in each manufacturing facility. This is a common approach when implementing lean manufacturing: drive the culture with the tools. However, that critical evolution where the tools create the culture is difficult. The next section will talk about the implementation period for GMS, a prime opportunity to create the lean culture and achieve true long-term success.

Section 3.5 GMS Implementation

This section contains a model for successful GMS implementations. The goals in such processes are two-fold. The first is to implement GMS in such a way that it becomes an indispensable part of the culture and therefore lasts through changes in management, model year, and technology. Goal number two is that the culture evolves to one focused on eliminating waste, not only implementing the tools to look good on the scorecard. By accomplishing these two goals, the plant – and the company - will realize the full benefits of GMS implementation.

This section is structured in a way that first presents the model for successful implementation and then outlines some keys to success that will enhance the model's effectiveness. The model and suggestions were created specifically for brownfield operations. However, it is applicable in most situations[6]. A key difference between brownfield and greenfield sites is that the implementation process in greenfield sites creates a culture where one has not existed. Contrasted to this, brownfield implementation has the somewhat more challenging task of changing the existing culture to one of lean thinking.

The problem of implementation of lean manufacturing processes is rarely due in large part to an inability to understand lean tools. Rather, companies struggle as they try to change their culture. The following section quickly outlines the concept of culture in order to put the implementation model in context. Following this description, the implementation model based on and understanding of GM's culture and how culture change takes place.

Section 3.5.1: Corporate Culture: A Brief Description

The culture of a particular organization is a set of assumptions and norms that it has developed over time. It is essentially what the organization has internalized and therefore, takes for granted as it conducts its business. According to Schein (1992), this culture is a result of an organization's attempts to cope with problems it has encountered both internally and externally.

[6] The model was presented to plant engineers and management in GM greenfield organizations as well as outside organizations that had to make large-scale changes. It was anecdotally deemed applicable in other organizations and in various situations.

Generally, strong cultural elements in an organization lead to a more consistent and high-performing business (Sørensen, 2002). The unity that a strong culture provides a firm leads to an ability to act within a set of norms that is acceptable to all members, thus providing evenness and self-correcting organizations. However, this strong culture also adamantly resists change. When environmental factors change and require a new set of operating rules, the ingrained norms create strong barriers to any significant changes in how the firm operates.

Therefore, change in the culture is very difficult to achieve, especially for large organizations and those with strong cultures. Research suggests that in order for a culture to last, it must be institutionalized (Sørensen, 2002). Institutionalization methods include:

- Selection of the organization's members to fit with the culture desired
- Creation of an organizational structure and other management structures, such as incentive structures, that encourage cultural elements desired
- Visual symbolic gestures throughout the transition period that signify the importance of the cultural change
- Demolition of symbolic cultural artifacts left from the "old" culture

As many of the formal structures are reflections of the culture, much of the institutionalization process is tied to the symbols of the culture. Therefore, as one attempts to create or change a culture, the symbols he uses during the process are as important as, if not more important than, the mechanics of the change.

Section 3.5.2: Implementation Model

The author created the following model by interviewing managers and engineers who have overseen implementations of GMS at greenfield operations and observation of several brownfield facilities in the midst of the implementation process. The LCC GMS implementation project provided an excellent basis for this model.

Lansing Craft Centre based their implementation on the benchmarked lean conversion in Belgium at an Opel plant (Mothersell et al., 2001). The key learning from this benchmarking study for the leaders at LCC was that to be successful in a brownfield lean implementation, a plant must systematically change to a lean model instead of trying to implement lean tools in a piecemeal fashion[7]. Additionally, Opel used what was referred to as a "guided" implementation, as opposed to one that is directed from headquarters and undertaken primarily by plant personnel. LCC's interpretation of a guided implementation was a structure including GMS Implementation Center experts. In essence, the engineering staff owned the lean conversion and acted as the leaders in the process. However, they had experts from the GMS Implementation Center to make sure that the project progressed and covered all of the necessary elements. These experts also helped to train the engineers and managers that eventually trained the union membership.

Figure 7 shows the model for GMS implementation based on the author's research.

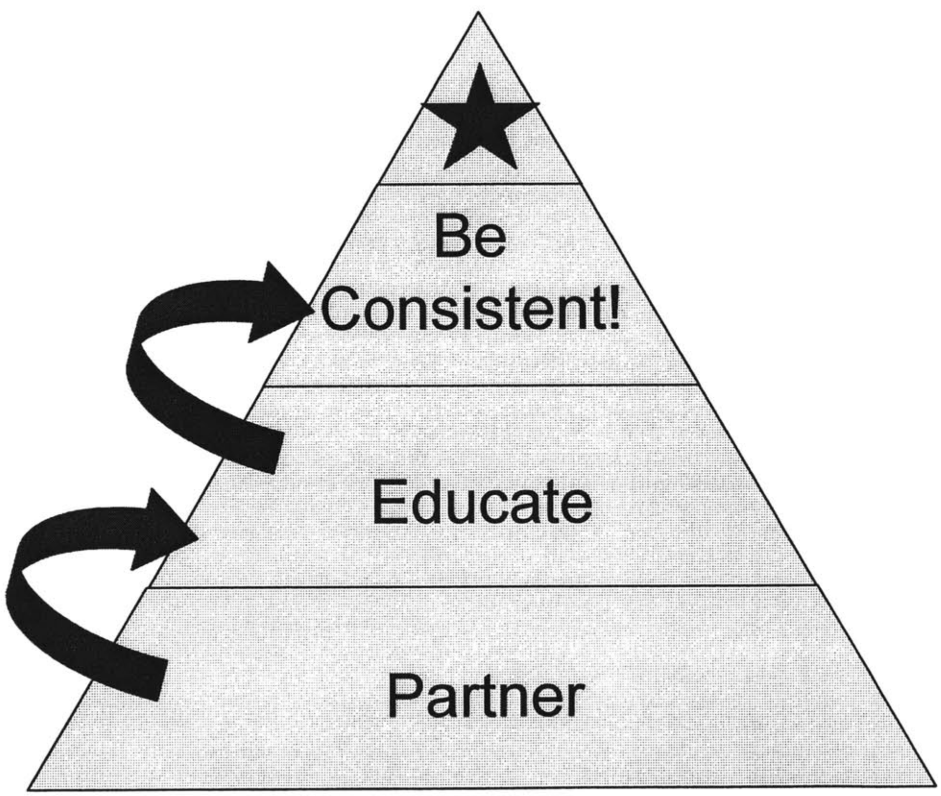

Figure 7. GMS Implementation Model

<u>Partner</u>

To interpret the model, one should start at the bottom layer, or the foundation for the entire project – creating the right team with a complete set of stakeholders. At a

[7] Many American companies, including GM, have tried implementing lean tools individually. This style of implementation failed to produce the results that a lean manufacturing system offers, and often led to discrediting of the entirety of lean manufacturing practices.

manufacturing facility, the obvious and critical members of this partnership are the plant manager and his staff, the local union representation's top officials, any major suppliers (especially if partners are involved impacting the program elements in the execution portion of the program), and GMS experts. This partnership needs to be explicit and involve people that will serve as representatives of their constituencies throughout the change process. Whether one has created a team of the "right" members depends on two major criteria. First, the person must be in a recognized leadership position in his or her constituent group and must have the respect of those he or she is leading. Therefore, their outspoken endorsement of GMS will be a significant symbol to those he or she leads. Second, the partner must truly believe in the GMS vision. This will be the most difficult requirement to fill in constructing these teams.

Finding the right people for the partnership team is so critical that time must be allocated early on in the project for this effort. The process is a bit of a catch-22, in that most people do not fully understand and believe in lean manufacturing until they have seen it and worked within the system. However, the team will usually have very few options to involve people who have lean experience (with the exception of the GMS experts who will be involved). In order to build the true confidence in the vision of lean operations, there are several creative methods that the program leaders can use. Each of these falls into the next layer of the model, which is education. Note that the partners should go through several rounds of education before the rest of the team gets involved in the lean conversion.

Educate

Education is how one can begin to build the culture that is necessary to run a lean facility. There are many types of education; classroom activities are only one available method to educate. The first iteration of education should be with the core partnership group. Before going into the details behind this level of the model, there are some absolutes that must surround each education experience in order to be truly successful. First, education must be an escape from the normal routine. This means that it must be a time sacrifice for both the employer and the employee, as this sacrifice demonstrates the importance of the training. Whether for management or floor-level operators, the educational experience must allow for true reflection and absorption of the lean concepts.

This is a sacrifice to the plant and the company in the short term. However, the payoff is an environment where the learning is taken seriously, the concepts are truly understood, and which fosters an open dialogue about the changes lean manufacturing will bring. This removal from daily responsibility is also a strong symbolic gesture to the trainee. When the company is willing to have their employees spend this sort of isolated time away from their daily duties, it emphasizes the importance of the subject matter.

Removing workers from their normal jobs is a sacrifice, and the ability to do so is the most commonly cited practical difference in greenfield and brownfield lean start-ups when talking to plant managers and manufacturing engineers at General Motors. Plant management often expresses frustration that they are held to production targets during the lean changeover. Therefore, lean conversions at brownfield sites often try to squeeze in bits of educational activities without taking operators and managers away from their normal daily operations. Creative solutions to the problem exist. For instance, there are downtimes for model changeover and allocated training periods that can serve as training immersion opportunities. The addition of another shift to the operation is another training opportunity. New personnel can be brought into training early so that when they start, they use GMS principles. After this training period is over, the new employees should take over one of the existing shift's operations, allowing that group of employees to take the time for training. While it costs slightly more in personnel, this avoids any potential lost production and results in a successful education phase of GMS implementation.

Education will normally start in the classroom with education about the vision and benefits of the lean environment and some particulars on the different ways to achieve the vision. Included in this discussion will be the TPS toolset and information about what makes a lean organization work. Experiential learning opportunities must be interspersed with this classroom activity.

General Motors has developed several levels of l earning environments that help to demonstrate concepts learned in the classroom. Simulated manufacturing environments allow employees that never get to work on the line to experience the line's daily pressures and difficulties. These training sites also allow a direct comparison of the differences in traditional GM manufacturing and that under GMS.

Other resources that are important in this experiential education are the plants that are running full lean operations. These facilities are useful models for observation and represent an important learning opportunity for managers and operators. The personnel in the GMS facilities understand what it is like in the lean environment and can serve as mentors for the employees involved in the transition. Opportunities to shadow operators and managers in the same job or in related positions are also invaluable learning experiences.

Be Consistent!

Day-to-day consistency will determine the success or failure of the implementation. The most common resistance in GMS implementation will be that the system is the "flavor of the month," supported by management only temporarily until the next management fad gains favor. Consistency throughout the process and after the formal education process is the only way to avert this skepticism. Most of the burden for this part of the model rests with the management, and to achieve consistency, these employees will need to change how they conduct business every day. At the first sign of the old system's mindset, employees will discount the entire GMS effort. Therefore, this consistency is absolutely critical.

An Illustrative Example of the Importance of Consistency

The author created Figure 8 during one of the first on-site GMS training sessions she attended at the Lansing Craft Centre. This structure is called a "causal loop diagram," and represents the feedback structure in the system (Sterman, 2000). The arrows between the different concepts represent relationships and influences between the different variables. Each arrow also contains a positive (+) or negative (-) sign that indicates the "polarity" of the relationships between the variables it connects. A positive relationship corresponds to the event that an increase in the first variable leads to an increase in the other (or likewise, a decrease in the first causes a decrease in the second). A negative relationship results when a change in the origin of the arrow leads to the opposite effect in the terminus of the arrow.

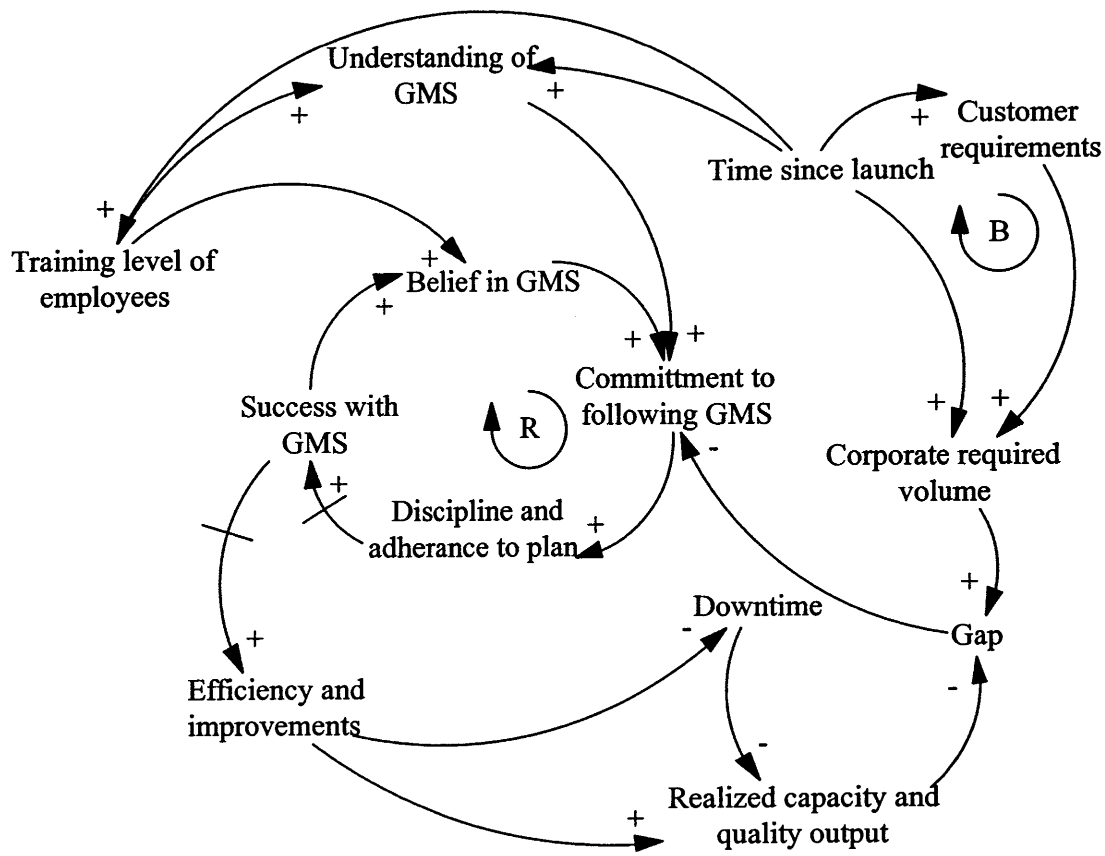

Figure 8. System Dynamics Model for Consistency in GMS Implementation

The feedback loops are represented by a "B" (denoting a Balancing loop) or "R" (denoting a Reinforcing loop) with a circle indicating the direction the loop is depicted in the diagram. The lines perpendicular to the base of the arrow denote delays in the effects between the origin and destination variables.

This particular causal loop diagram is intended to demonstrate the dynamics of the implementation of GMS in the context of the corporate pressures on any vehicle program. It was created during a discussion in a GMS training class about how the managers, who were the students in the class, should talk about GMS to their reports. The contention was that certain GMS elements, in this case, the *andon* system, should not be emphasized as absolutes, because as the expected production volume of the factory increased, there may be times when employees will be encouraged not to pull the *andon* cord every time they encounter a defect. This decision may be made in accordance with the business restrictions at the time, but the employees will see it as a breakdown in the whole system of GMS and therefore discount its merit in general.

The discussion troubled the author a great deal, for if managers were already backing off from the GMS elements while it was easy to focus on implementation, there would be little motivation to be disciplined when the pressures mounted (which they most definitely soon would). In essence, the best time to be rigorously following the changed process is the first part of the manufacturing launch. Expectations for volume will always increase, and although there may be a delay in the effects of lean manufacturing implementation, long term success will come more easily if management sticks to the lean manufacturing implementation plan consistently through the early stages of production. This may cause short-term losses in production, but eventually, it is the only way that the project will be successful.

The causal loop diagram illustrates this by showing the positive, or reinforcing loop, which occurs as more employees are trained in and get experience with GMS. This slowly leads to a commitment to follow the principles and procedures associated with the system. As this becomes standard practice, the plant will start to see increased efficiency and improved quality output, which will allow manufacturing to more easily achieve their production targets on a daily basis. However, this loop takes time to impact the system, and this time may allow a balancing, or negative, loop to take control.

Company-driven pressure creates this negative loop as a plant ramps up a new vehicle. This pressure increases the gap between the realized capacity and the expected or required capacity for production of the vehicle. This shakes production management's resolve to follow any procedures that result in short-term production losses. For example, supervisors may encourage their employees to refrain from stopping the line for quality defects, trying to fix any problems while the line is still moving. Deviating from the GMS principles without a GMS-consistent decision process and adequate explanation to the production workers will cause general distrust of GMS as a whole, weakening overall commitment to the system. In turn, the production efficiencies and quality improvements that could be gained via lean principles will never be realized.

What this diagram illustrates is the importance of consistency. The early stages of GMS implementation will require patience while the positive effects of lean have a chance to take hold. Management must recognize this need as well as anticipate the pressures they will experience from the organization. Only through this recognition and the subsequent reaction will leadership be able to create the culture that supports GMS.

How To Be Tactically Consistent

Daily consistency means that management must act according to the principles of GMS. This will mean that communication will be an essential part of daily operations. Any decisions made by management must be accompanied by an explanation. Some decisions may appear to be inconsistent with GMS principles, but may be made only after GMS countermeasures are in place, the situation is understood, and the business environment dictates a course of action. Under normal circumstances, employees would only recognize the action and not the reasoning behind it. Management must ensure that this is not the case in the GMS environment. In fact, the environment must be inclusive enough that employees on the lines are an integral part of the decisions that run the plant.

The Organization Must Also Support The Effort

Organizational consistency is important as well. Metrics by which the plant is measured and rewards are decided must support the GMS mission and the company's culture. General Motors has created an excellent balanced scorecard by which it measures its plants' performances quarterly. Annual GMS audits also measure the specific adherence to lean manufacturing principles, and are prioritized equally with the quarterly reports by top management of the company. Because culture and people are difficult areas in which to measure success with scorecard-like metrics, these are the areas that are least developed. Although training hours per employee and numbers of suggestions are pieces of the culture, these metrics can indicate success without the real objective being met. Do these metrics really measure if employees are empowered? There is no easy way to measure employee empowerment without creating goals that can be achieved without actually achieving meaningful employee participation and empowerment. The point is that in order to avoid sub-optimization, qualitative measures are important in addition to quantitative metrics. Successful management will need to be in-touch with its organization and culture, which is not something that is always rewarded. However, overall, the approach at General Motors is very comprehensive in this respect.

This model represents the overall process that leads to the most efficient and effective lean manufacturing conversion in General Motors plants. Although simplistic, following the few steps outlined above will create the potential for long-term success of GMS at General Motors. The model's content has also been validated by leaders outside of General Motors, as outlined in a speech that Mike Duffy, Vice President of Value Chain at Gillette, gave to an MIT class on April 7, 2003. His keys for success in organizational change were very similar to the model outlined above and provide an additional validation of the model beyond General Motors.

Section 3.5.3: Keys To GMS Implementation Success

The model described is a methodology to guide the process of implementation of lean manufacturing in terms of the steps necessary to achieve success over a long period of time. In addition to these steps, there are some other tips that can aid in GMS implementation in the General Motors culture.

It takes a great deal of time and patience to change a culture. As mentioned before, academic research on cultural change outlines several guidelines, such as the use of symbolic gestures that act as visible signs that things are changing for good. These symbols back up talk of change to solidify the need to move with the uncomfortable changes.

In the large, diverse GM environment, symbols will assist as GMS changes the culture of manufacturing and its support functions. One such symbol that has been effective in prior GMS implementations is the association of the GMS changes with a change in the manufacturing facility itself, whether because of a new model year, updated technology, new work structure, or other large-scale change. Another symbol was mentioned in the implementation model above. The removal of personnel from their daily activities in order to attend training activities not only signifies the importance that the management places on GMS but also creates a focused and open environment in which effective learning can take place.

Involvement of the right people and the right organizations is also critical. This key success factor was mentioned in the partnering portion of the implementation model but is crucial throughout the process. The right people must fit in terms of both their position in the company and organization as well as in their mindset toward lean manufacturing.

Additionally, as GMS permeates the organization, it will be important that functions outside of manufacturing understand lean principles as well. Engineering, Design, and Procurement staffs all make decisions that are integral to the operations of the manufacturing facility. Without understanding the vision and principles of GMS, many decisions made upstream from the manufacturing execution portion of the program may hinder lean manufacturing practice in the plant. While these decisions may serve organizational goals, such as piece part cost reduction, they may be in direct conflict with the manufacturing's ability to execute efficiency. GM management seems to understand this a bit, as at the end of the six-and-one-half month period at the company, there was a proposal to change the name of GMS so that it does not contain the word "manufacturing." Although some resisted this, it demonstrates the recognition that this system must transcend the organizational boundaries beyond manufacturing to be truly successful. Finally, top management must also be a part of the cultural change. For this reason, GM must continue its education of its executives in GMS principles because its concepts must permeate the entire company.

Taking the time to achieve the cultural change and accepting that it will not come easily or quickly will be difficult for management as plants implement lean principles. However, committing to the change and the transition period will result in great rewards in the long term.

Section 3.6: Chapter Summary

Lean manufacturing has become the standard for efficient operations. However, the true benefits come from building a culture that is committed to the elimination of waste in every process. While lean manufacturing tools are ways to counteract waste, the true benefit of lean is not in the tools themselves, but in the mindset and culture. In order to document the lean principles, GM created their Global Manufacturing System, or GMS. Although the focus of GMS is the tools, successful implementation may serve to change the culture enough to create the right mindset for operational excellence.

The model for GMS implementation is not complex, but successful execution is definitely not easy. Following a simple model and creating visible symbols that signify that the change is important. Partnering the correct groups (including GMS experts, plant owners, plant management, union leadership, and key suppliers to the program) and creating a core team of the major stakeholders to guide the process is the first step. These people must then be educated so that they buy into the GMS mindset and will be effective ambassadors as the rest of the manufacturing facility transitions to lean. Next, the overall employees must be educated in an environment that removes them from their daily responsibilities and the "old" way of doing things. Finally, GM must practice diligent daily consistency with the GMS principles and reward and measurement systems that support the keys of lean manufacturing excellence. To build momentum behind the change process, symbolic gestures that are consistent with GMS as well as the GM culture are important.

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Chapter 4 : Lean Manufacturing In Low Volume Vehicle Environments

This chapter deals with the implications of the low volume manufacturing environment on GMS implementation. Additionally, it exposes areas where the GMS implementation process and philosophy may need to evolve in order to fully achieve GMS's goals, especially in low volume environments.

Before this discussion, it warrants a reminder that the essence of lean manufacturing is not in the tools by which many companies define it, but rather in the philosophy and effectiveness of continually eliminating waste in all areas of the organization. Rigorous focus on this aspect may call into question the standard toolset at times when the implementation situation is different from the norm. With this mindset, one can perform a constructively critical analysis of the best way to implement GMS in a halo vehicle program.

Section 4.1: Elements of Low Volume Vehicle Programs Relevant to Manufacturing

As stated earlier, manufacturing strategies in low volume programs often differ from their higher volume counterparts. In order to profitably pursue low volume programs, GM needs to get products to market quickly while minimizing product development overhead and capital investment. These products must be well designed and manufactured through efficient operations if the company is to realize benefit from the strategy.

These constraints that help the program achieve financial success also have implications on manufacturing strategy and in turn, the manufacturing facilities that produce the vehicles. Low volume programs' manufacturing strategies differ in how plants are structured (e.g. how many lines in paint shops, body shops, assembly centers – if any), how much of the product is manufactured and assembled in-house (versus outsourced), the number, size and product mix of manufacturing facilities, and the amount of the overlap that the product has with other products' designs. These strategic considerations affect the manufacturing facility in structure, process, and management.

Low volume vehicles are manufactured in environments with different characteristics from their large, efficiency-driven, economies-of-scale counterparts for high volume programs. Plants running lower volumes generally have longer cycle times per assembly station due to the lower demand and resulting longer *takt* time. This results in higher work content per assembly worker and more individual responsibility for the final quality of each vehicle produced. Another consequence of low volume manufacturing on the plant floor is a work station footprint that is compressed relative to the amount of work done in each assembly station. This leaves little room for all the raw materials needed for these expanded jobs. Production scheduling may also be impacted, based on the manufacturing strategy for product mix at a particular plant. Depending on the variety of vehicle architectures present in the product mix at a plant, different scheduling techniques may be necessary than in higher volume vehicle plants. Small batching in product runs may be less wasteful than high-complexity changeovers between each vehicle on the line (Veeravagu, 2001).

Because of all of these differences in low volume production environments, implementing lean manufacturing necessarily presents different challenges for these programs than for operating high volume plants.

Section 4.2: The "Lean in Low Volume" Problem

Although lean manufacturing has its roots in smaller manufacturing environments of Toyota's early production (Fujimoto, 1999), the organized operating systems companies have created to standardize lean in their own organizations are generally optimized for high volume settings. In order to take advantage of the benefits of lean manufacturing's waste reduction philosophy, there has been a trend of lean research for industries that are inherently low volume, such as the aerospace industry. Results of this effort include the Lean Aerospace Initiative at MIT, which has sought to create standards for lean manufacturing in the industry environment where demand for any one product may be even less than five per year.

Low volume vehicle manufacturing has its own set of constraints and characteristics that set it apart from many other industries that are struggling with how to implement lean in their production environments. Operations differentiators between high volume and low volume are summarized in Figure 9.

Traditional High Volume Vehicles	Low Volume Halo Vehicles
Many vehicles per day (year)	Relatively few vehicles per day (year)
High volume of production over which fixed costs can be spread	Few production vehicles to absorb fixed costs for capital equipment and development
Short cycle times for each operator	Longer cycle times (by at least five times, as determined by current low volume standards at GM) at each station, leading to more work content per operator
Generally limited mix of vehicle architectures on any one production line	Potential for highly-differentiated vehicles with different base architectures and manufacturing requirements on one line
Standard footprint for operator's assembly station	Standard footprint, but more work content to fit inside this footprint, resulting in a relatively compressed workspace
Quality and reliability expected by customers	Even higher customer expectations in terms of style, quality, performance, delivery to the market
Quality targets can be achieved even with a few errors	Each vehicle represents a more significant portion of daily production and therefore is essential to meeting quality targets. Therefore, line workers have an increased responsibility for making sure the work is done correctly.

Figure 9. Operational Differences Between Traditional Manufacturing Environments and Halo Vehicle Manufacturing Environments

Despite these differences, GMS is a key enabler to the long-term success of the halo programs. As discussed in Chapter 1, the competitive nature of the low volume vehicle market forbids passing the costs of inefficiencies in manufacturing and less-than-scale-economies in capital and developmental investment on to the customer. Therefore, the waste elimination mindset and ability that comes with GMS implementation is critical if the economics of these programs are to succeed. Another driver for this criticality is the necessity to bring vehicle designs quickly to market in order to take advantage of style trends. GMS's implementation provides an efficient and standardized process for starting up new vehicle programs from a manufacturing perspective. This further enables success in these low volume vehicle programs.

For General Motors, then, it follows that the company cannot be truly successful in their low volume strategy without manufacturing efficiency and flexibility allowed by lean manufacturing. Unfortunately, there is little research that applies to GM's situation and will assist them in understanding how to implement their lean manufacturing system appropriately in low volume vehicle programs.

Section 4.3: Low Volume Implications

As a result of the differences in low volume manufacturing environments, some of the implementation details of GMS will need to vary from higher volume manufacturing implementations. These differences are grouped into categories and discussed in this section.

Section 4.3.1: Low Investment Implications and Considerations

Investment in capital and development costs must be limited to allow the vehicles in low volume programs. However, some investment is necessary. What must change in a low volume environment is the proportion of the total investment dollars that are dedicated to different parts of the program. For instance, the proportion of the total investment that is spent on new capital equipment will most likely be smaller for a low volume program than for a higher volume vehicle. Some specific differences in GMS-related investments follow. These are not meant to form a complete list, but they were all issues that arose during the author's observations of the SSR program.

<u>GMS Tools</u>

First, the standard GMS tools and equipment have been developed over years of experience with high volume lean implementations and robust operations within these environments. While these tools will undoubtedly function well within low volume environments, they might be too costly to put into a halo vehicle program. As an example, the *andon* systems that have been developed are comprehensive and well-suited for large, sprawling manufacturing facilities. However, in low volume environments, where investment dollars are necessarily limited and the square footage of manufacturing floor space is smaller, these extensive systems are impractical and excessive. Additionally, they cannot be justified because the cost of such technology-intensive systems is too large to be profitably spread across low volumes of vehicles.

In these situations, the key to solving the dilemma is to remember the essence of lean manufacturing is the elimination of waste. With this mindset, it is clear that not following this standard creates less waste than investment in such a complex solution to an easy problem. In this example, one must remember that *andon* simply means "lantern," or a signal that will allow a line worker to signal that there is an issue with which he or she needs assistance. Low investment solutions abound, such as simple lights that can be illuminated by operators that are visible within the zone where they, their supervisor, and their team leader work. This may or may not be connected with audible tones that will accommodate visually impaired workers and assist in signaling help. This low-tech option achieves the overall intent of the large *andon* systems without a large, potentially crippling investment

In short, there are many creative solutions that are possible when the low volume of a vehicle program demands a less investment-intensive alternative. This may appear to violate GMS principles, but upon further consideration and with the spirit of lean thinking in mind, it is obvious that this is no breach. Instead, it is an application of the concept of waste elimination to the need to allow operators to signal for help while they are working on the vehicles on the line. While it is true that it may create the need for an additional process for maintaining the equipment, in reality, these solutions will be so simplistic that the addition will not be burdensome for the engineering organization.

Other Standards

In contrast, there may be examples where investment may be the best option in low volume vehicle programs, even if higher volume programs would not need such investment. Take for example the issue of standard raw materials containers. These containers are standardized and reused in all vehicle programs, but the use of these same containers for low volume programs creates a tremendous amount of waste in the system. A particular container may save on shipping and storage in a high volume environment. However, it might also create floor space problems and shipping problems because the number of units per container is a significantly higher percentage of the total daily volume in a low volume facility. Redesigning these containers may be somewhat costly, but without a smaller form factor, they might become physically constraining in a low volume environment. With an intelligent design, the investment may be applicable to other programs or parts as well. Although these programs need to minimize investment, strategically sound investment that promotes waste reduction without over-investment is prudent.

Section 4.3.2: Manufacturing Strategy Implications

Previous sections have outlined which elements of manufacturing strategy may change between low and high volume vehicle programs. Some of these are controlled by the manufacturing organization, and these are the topic of this section.

Specifically, the production control organization may need to adjust their application of lean principles depending on the mix of vehicles in production at the plant. Lean principles dictate that a plant should run without batch production. It is true that phasing out the large batches that were characteristic of previous mass manufacturing systems eliminates a tremendous amount of waste in a manufacturing facility. However, there may be times when small batches are less wasteful than a process that would require tremendous changeovers for each vehicle. For instance, in a case where several radically different halo vehicles are produced at the same manufacturing facility, the amount of lost production necessary to change the line over between each vehicle and the cost necessary to build in massive flexibility may overshadow the waste that is created by producing each model in small batches.

While study has shown that this is the most efficient way to run the facility in these circumstances (Veeravagu, 2001), the notion that batches are inherently "bad" permeates the GMS implementation organization at GM. Although any batch production violates the strict GMS requirements, this special case warrants consideration. This is one example where the standards limit the flexibility that is needed to truly run with the least amount of waste in the system. Because the tools themselves have become the focus of GMS instead of the mindset that evaluates each situation with its unique set of circumstances for the best way to eliminate waste, this is a difficult conversation with GMS personnel and with those trying to learn the system. It is precisely this type of situation that best demonstrates the need to build the culture and understand the evolutionary learning capabilities (see Chapter 1) that are the backbone of the Toyota Production System.

In situations such as these, where different factors affect the overall situation and call into question whether a lean tool should be used, there is a conflict. To resolve this conflict, the analysis should consist of a close examination of the waste that use of the tool causes versus the waste that the tool is meant to save. In some situations such as the production scheduling example above, the relative amount of waste that the tool saves is miniscule when compared to how much waste is built into the alternative plan. This sort of waste cost-benefit analysis, if done thoroughly, will lead closer to a truly lean manufacturing strategy.

Section 4.3.3: GMS Elements That Differ In Low Volume Environments

Because the lean manufacturing mindset of continually eliminating waste provided the base for the tools that are identified with the system, most of the GMS elements are completely applicable to the low volume vehicle strategy. Instead of outlining differences in individual elements, this section discusses a specific group of closely related concepts that requires modification for low volume facilities.

Visual Controls

Visual controls include *andon* systems and other plant-wide complex technology systems, which have been discussed previously. However, there are more complications to consider in the area of visual controls. For instance, GMS dictates that each work station should have standardized work instructions for the operators there. This ensures that the job is done consistently and completely every time, no matter who the operator is at the moment. However, in a low volume plant, each operator will have work content that takes multiple minutes, instead of the minute-or-less cycle times for operators in normal plants. When trying to detail such a long and complex operation, the operator will discover that the documentation is also long and complex, resulting in a standard operating procedure that is all but unusable in the production environment. These job instructions will be too unwieldy for on-the-job use. Finding a solution becomes even more important in a higher mix environment, where the documentation will be referenced more, as highly differentiated products flow through the line. Rotation through jobs in a low volume environment only emphasizes the need for an elegant solution even more. Without a good solution to this visual control issue, quality and productivity will suffer.

Innovations in this area are critical, because achieving standardization on the line is a key step in achieving success with lean manufacturing. Perhaps different formats for documentation are required. For instance, a summary record that highlights the key steps and can act as a reminder for a new employee would be a more useful format for higher content operations. If investment money is available, video format instructions can assist operators in performing standardized operations. Creativity balanced with careful understanding of the actual constraints and operator needs will alleviate the issues around standardized work documentation.

Relationships That Change Between Elements

Other GMS elements are easily applicable in both low and high volume facilities. In fact, some are even more important in a halo program because of the fact that they reduce waste and lead to more efficient production, which is central to success at low volume. These include a robust quality system, continuous improvement discipline, and a highly developed and supported workforce. However, in one particular case, the relationships between the concepts change from a high volume application to one in low volume.

This relationship is between an element of the People Involvement principle and that of Built-In Quality. Specifically, one of the ways that GMS proposes that a plant develop its workforce is to rotate operators through workstations on the manufacturing floor. By learning multiple operations, employees can recognize defects in the process more readily and assist in their quick resolution. This in turn leads to higher built-in quality overall. By contrast, in the lower volume assembly environment job rotation may lead to more quality defects because it takes much longer to become an expert on a complex job such as one found on a low volume line. While the quality impact may turn out to be positive over the long-term, it will take quite awhile for the negative effect of the learning curve on job rotation to turn into the positive quality improvements this element is trying to achieve.

Solving the visual controls issue discussed above is a major step toward enabling the benefits of job rotation without the setbacks in quality that are probable in a low volume manufacturing facility. With powerful instructions that help the operators learn the job quickly, success is possible. However, in order to maintain the quality standard to which

GM operates, management must be sure to understand the implications that following GMS's guidelines may have on the overall system.

While the LCC may not struggle with balancing the work content versus quality issue, its success will hinge on the skills it has developed over the years as a low volume manufacturing facility. Consequently, the workers are craftsmen rather than pure operators that would be found in most GM facilities. Although the quality and cost focus that has been successful at LCC suggest that GM can develop these environments and skilled workers, developing these skills will take time, and this will have an impact on the expansion of the low volume strategy. Therefore, GM will need to solve the visual control and training issues presented in this section if it chooses to continue on its low volume vehicle strategy path.

Section 4.4: Chapter Summary

GMS is a key enabler to any low volume vehicle program because of its positive impact on the bottom line. However, the application of lean principles differs in a lower volume production environment from those that run at higher volumes. A major difference for implementation of GMS is the cycle time and level of work content found in a lower volume facility. This complexity in each operator's work leads to difficulties in creating useful standardized work instructions and achieving benefit from job rotation. In response, GM will need to further assess creative options that result in solutions that are useful to workers in a low volume environment.

The rule to remember in lean manufacturing is to focus on the key tenet: continual elimination of waste. This is sometimes in direct conflict with the tools that GMS may require in implementation, such as mixed lot production. When in doubt, one must truly examine the potential waste created by the tool as well as the waste that the tool is meant to counteract. With this sort of waste cost-benefit analysis, it is possible to make truly lean decisions.

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Chapter 5 : Conclusions

This chapter summarizes the key goals and strategies discussed in earlier chapters and presents some additional recommendations for General Motors as it continues in its low volume vehicle strategy.

Section 5.1: Summary of Low Volume Vehicle Programs

In addition to changing market conditions and resulting changes in consumer preferences, automakers are responding to a potential market that will easily reach $20 billion over the next five years – low volume vehicle programs. Providing potential customers with highly styled vehicles that do not necessarily appeal to a mass market is a challenge for automakers, which are accustomed to spreading overhead costs over a large volume of vehicles.

In order to be successful in this endeavor, low volume programs must operate within different constraints than those that will result in higher volume, mass market vehicles. The major differences are as follows:

- Investment in development costs and capital equipment must be kept to an absolute minimum. This is necessary to keep the overhead low and allow the vehicles to be both affordable for customers and profitable for automakers.
- Product development must be efficient in timing as well as cost. Because the designs are more stylish and dependent on trends that come and go more quickly than a normal vehicle program's lifecycle, the ability to sell the vehicles developed under this strategy depends on getting from concept to showroom floor quickly.
- Operations during the execution phase must be run efficiently. Any waste in the system will further challenge the profitability of the program. Additionally, the programs will most likely require quick movement through the learning phase, as vehicles will change more often than the mass production models.

These changes in the program requirements for low volume vehicles drive the need to develop internal skills in several areas. This thesis addresses two: lean manufacturing and outsourcing/partnering. The partnering skill will help to achieve the quick and efficient product development as well as offer some efficiency during the execution phase of the project that will help operational efficiency. Lean manufacturing and the lean mindset address both developmental and execution efficiency as well. However, in order to be successful, GM will need to develop these skills to the point where they will offer the benefits that will allow low volume programs to be profitable.

Section 5.2: Outsourcing and Partnering Recommendations

GM needs to carefully consider the partnering and outsourcing decisions in the context of its corporate strategy. In particular, the long-term strategic consequences of any outsourcing decision need to be considered up front. GM needs to understand its core competencies that differentiate the company from its competitors and potential competitors. From this strategic position, a well-informed overall outsourcing strategy will develop.

Even once the strategic context is established, the high-level strategic work is far from over. At early points in the partnering decision, someone from a cross-functional and high strategic level must be involved. Each individual element that could be outsourced will play into the strategic framework differently, and a decision maker with authority and systematic motivations must be the one resolving the strategic tradeoffs. Because each element that may be outsourced will be of different importance to the customer, will have a different supplier base, and will be more or less available within the company, each element must be given individual consideration. Many of these considerations will require someone at a high level to be involved in looking at the strategic and systematic implications of any sourcing decision.

Once a decision is made, GM needs to choose the right partners and then manage the partnership. This management portion involves many key success factors, including:

- Leverage each partner's core competencies – The main reason to enter into any partnering relationship is to take advantage of the different core competencies that the partner has developed. However, GM needs to be cognizant of what it can bring to the program from the perspective of its own strengths. In essence, if partnering is used in a vehicle development program, GM needs to leverage its strength in complex program management to its advantage, even if other companies are involved. In essence, the strengths from the different partner companies need to be pooled to create an "extended enterprise" that can function at a higher level than any of its individual parts. This might influence the role that each player may take on in the program. GM may need to act as the program manager, even if it takes on many partners for the program development and execution. Other partners will have other competencies they can leverage. For instance, one may be able to leverage their size and contacts with suppliers for buying power. In the end, the increased synergy as a result of this competency leverage will benefit the whole program as well as the partners.

- Build the right team early – Partners that are involved in a program need to be an active part of the team early on, even if their main focus is in the execution or downstream processes of the program. It is especially important to have manufacturing involved in the design, engineering, and procurement portions of the program, even though these partners will not be focusing on these activities. The insight they can provide and the planning they can do with up-front involvement will increase the success of the entire program.
- Establish clear boundaries – GM needs to avoid any program ambiguity caused by unclear expectations of duties among the partners. This has happened in the past when high-level instructions have left a tremendous amount of gray area in each firm's responsibilities. This kind of inefficiency and potential for error is a certain way to fail in low volume programs. The resulting delays in schedule or quality degradation will mean that the vehicles are difficult to sell and consequently unprofitable. Therefore, documentation detailing the owners of each activity and the respective boundaries of the activity must be clearly communicated to the partners in the extended enterprise.
- Communicate! – Like establishing clear boundaries for the responsibilities of the program, GM and its partners will need to establish a common language and a communication process that allows for efficient dialogue and collaboration among the team members. This process must include a detailed program plan that includes agreed-upon internal and external deliverables. Even if the deliverable is not necessary for another partner, if it is important that it is done, it must be on this plan. This helps to establish trust and an expectation set among the partners in the extended enterprise. Finally, establishing a vocabulary of terms and documents will contribute

to the efficiency and effectiveness of the communications process, thus enhancing the success of the project.

Finally, GM needs to keep in mind that the decision to outsource also has internal long-term implications. For instance, if the company decides to contract a partner to perform a certain process in a low volume program, it will not develop the ability to perform this process in the future. This is especially relevant in low volume programs, which are new to GM. Although resources may be scarce in the short-term, the long-term effects of outsourcing may have far-reaching strategic implications. Therefore, from a strategic perspective, if important elements are outsourced, the partnership should be structured in such a way that creates a collaborative and educational pairing between GM and supplier personnel. The best way to learn something, however, is to actually do it. This consideration must be a part of the partnering decision at a strategic level if the element will be critical and part of the long-term strategy.

Section 5.3: Lean Manufacturing Recommendations

GMS is a critical enabler of success at GM, especially in low volume vehicle programs. Not only do lean practices enable efficient operations and cost-effective vehicle production, but they also can be enablers to achieving efficiencies in changing conditions. Lean thinking allows a context in which decision makers and individual contributors can develop the ability to understand the relevant constraints in the system, identify inefficiencies, and make waste trade-off decisions.

The key take away for GM in the area of lean manufacturing is to remember that the benefit of GMS is in the mindset that motivates everyone to focus on the continual elimination of waste, not the tools that make up the set of elements and core requirements. (These are essentially countermeasures to the waste found in mass production systems.) Following this logic, GMS auditors will need to adopt an intelligent and systematic view of each program and manufacturing facility, especially as more low volume programs become part of GM's product portfolio. Each program will have waste inherent in different places and in different proportions, calling for different applications of lean thinking. Leadership in the plant must be able to create a culture that enhances its employees' abilities to identify and eliminate waste, not just train the workforce on GMS tools. Further, organizations outside of manufacturing need to become lean experts as well. In addition to the benefits that they will realize with the adoption of lean thinking, these organizations impact manufacturing in the decisions that they make and enhance or detract from the overall waste in the system.

As an organization goes through the process of learning and implementing GMS, it should follow the simple model of "Partner – Educate – Be Consistent" presented in Chapter 3. Partnership before the process begins ensures that the stakeholders are involved in the entire process and are present as leaders for their respective constituencies. Education comes in different forms and will occur on an iterative basis. GM needs to leverage its current creative education techniques that allow for teaching beyond the classroom environment and continue to develop ways for employees to experience lean manufacturing. Consistency with the GMS philosophy and principles on a daily basis is most important part of implementation. This goes beyond using the tools all the way to the manner in which the business is run. Communication will need to be more frequent and thorough, and decision-making will need to leverage plant-floor-level employees as part of this consistency. Establishing consistent metrics and supporting incentives will help promote constructive behaviors.

Decision-making under a truly lean mindset will involve empowering employees across organizations and at all levels to look at issues systematically. True success does not involve applying tools but rather looking at the large problem, its context, and the tradeoffs each potential solution creates. Through this method, lean manufacturing implementation will easily evolve to accommodate low volume environments because the whole problem will be examined systematically and creative solutions determined.

Section 5.4: Final Conclusions

GM is well positioned to take advantage of the huge potential market in low volume vehicles. However, GM must be wary that the same standards that have allowed quick and abundant success may end up limiting the company's accomplishment in the end. True success hinges on its ability to further evolve the culture of the company to make systematic decisions instead of applying tools blindly.

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Appendix A: Low Volume Market Size: A Five Year Historically-Based Revenue Calculation

Ward's U.S. Vehicle Sales of Selected Low-Volume Vehicles (Calendar Years 1998-2002)									
Source: Ward's AutoInfoBank									
Brand	**Series**	**1998 sold**	**1999 sold**	**2000 sold**	**2001 sold**	**2002 sold**	**approx. 2002 price**		**2002 revenues**
Mitsubishi	MITSUBISHI 3000	4164	3419	117	1	1	$22,000	est	$22,000
Nissan	NISSAN	124	15	3	3	3	$55,000	est	$165,000
Nissan	ALTRA EV	0	30	50	38	72	$25,000	est	$1,800,000
Plymouth	PROWLE	1594	2365	2631	1053	166	$45,000		$7,470,000
Suzuki	SWIFT	2254	2290	3379	2547	177	$9,300		$1,646,100
Acura	ACURA	303	238	221	182	233	$89,000		$20,737,000
BMW	BMW Z8	0	0	317	970	524	$131,500		$68,906,000
Isuzu	VEHICROS	0	1271	1223	978	681	$25,000	est	$17,025,000
Hummer	HUMMER	0	0	875	768	720	$105,000		$75,600,000
Chrysler	PROWLE	0	0	0	1134	1328	$45,000		$59,760,000
Chrysler/Plymout	PROWLE	1594	2365	2631	2187	1494	$45,000		$67,230,000
Dodge	VIPE	1248	1315	1470	1388	1511	$73,000		$110,303,000
Audi	AUDI A8	2172	2481	2362	2300	1515	$63,000		$95,445,000
Lexus	LEXUS GS	9926	6894	6158	4613	1815	$36,000		$65,340,000
Honda	INSIGH	0	17	3788	4726	2216	$20,000		$44,320,000
Mercedes Benz	MERCEDES G	0	0	0	674	3114	$73,000		$227,322,000
Infiniti	INFINITI	8244	6271	4178	5726	3717	$49,000		$182,133,000
Jaguar	JAGUAR XK8	5861	6154	6729	5137	3935	$70,000		$275,450,000
Mercedes Benz	MERCEDES S	0	367	2204	3748	3938	$80,000		$315,040,000
Toyota	TOYOTA MR2	0	0	7233	6254	4705	$22,000		$103,510,000
Audi	ALLROAD	0	0	1033	6357	6007	$39,000	est	$234,273,000
Volkswagen	EUROVA	406	3395	2714	5600	6673	$25,000		$166,825,000
Mercedes Benz	MERCEDES	10620	10600	12930	11268	7784	$44,000		$342,496,000
Land Rover	RANGE	7070	7449	6287	5771	8549	$70,000		$598,430,000
Isuzu	AXIOM	0	0	0	5851	8989	$27,000		$242,703,000
Audi	AUDI	0	5139	12027	12523	9513	$32,000		$304,416,000
Honda	HONDA	0	3400	6797	9682	9684	$31,000		$300,204,000
Porsche	BOXSTE	9696	12681	13312	12278	9875	$42,000		$414,750,000
Porsche	PORSCHE	7547	8194	9098	10763	11443	$111,000		$1,270,173,000
Mercedes Benz	MERCEDES SL	7809	7853	5409	4217	13717	$85,000		$1,165,945,000
Lexus	LEXUS SC	3009	2557	631	14333	14462	$62,000		$896,644,000
									$7,676,083,100
	low volume market in 2002 prices:			$4,756,921,200	$5,242,866,000	$5,801,357,200	$ 7,208,103,100	$ 7,676,083,100	

Figure 10. Low Volume Vehicle Market 1998-2002

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