

# Re-sourcing Manufacturing Processes in Metal Forming Operations

by

**Heath M. Holtz**

BS Operations Research, United States Air Force Academy (1997)  
MS Operations Research, Georgia Institute of Technology (1998)

Submitted to the Sloan School of Management and the Engineering Systems Division in partial fulfillment of the requirements for the degrees of

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and

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Signature of Author \_\_\_\_\_

Engineering Systems Division  
Sloan School of Management  
May 6, 2005

Certified by \_\_\_\_\_

Thomas W. Eagar, Thesis Supervisor  
Thomas Lord Professor of Materials Engineering and Professor of Engineering Systems

Certified by \_\_\_\_\_

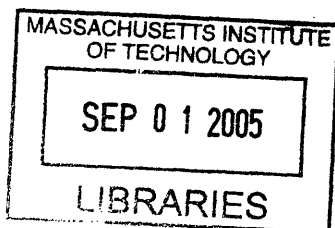
Stephen C. Graves, Thesis Supervisor  
Abraham J. Siegel Professor of Management and Professor of Engineering Systems

Accepted by \_\_\_\_\_

David Capodilupo, Executive Director of Masters Program  
Sloan School of Management

Accepted by \_\_\_\_\_

Richard de Neufville, Professor of Engineering Systems  
Chair, Engineering Systems Division Education Committee



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## **Abstract**

Deciding which activities to conduct in-house and which to outsource has become increasingly important due to its implications on a company's supply chain and overall business model. A number of factors can lead a company to outsource manufacturing processes. As a result of this outsourcing, the supply chain can become very complex and overwhelming to manage. This thesis will analyze this situation from the perspective of one manufacturer, American Axle and Manufacturing, Inc. (AAM).

AAM's Metal Formed Products (MFP) Division currently has a number of challenges: rising steel prices, fixed labor costs and declining sales. All these factors have significantly impacted profitability, forcing senior management to take a comprehensive look at the division and consider developing a plan to improve divisional operations. As a part of this plan, MFP Division's senior management asked for a thorough look into all of the manufacturing processes performed by the division both internally and by outside suppliers. In addition to identifying the processes and suppliers, senior management sought to highlight opportunities for improving the process flow through the re-sourcing of manufacturing processes. This project develops a framework to analyze and evaluate these re-sourcing decisions.

This framework employs a five-step approach and incorporates a number of diverse analytical tools. Process flow mapping provided a tool to visually highlight the best opportunities to re-source. In addition to a visual representation, process flow mapping also provided the data to financially evaluate alternatives. Strategic and market factors were identified in order to target and prioritize re-sourcing efforts. This framework provides a structure for sourcing decisions that balances the financial and strategic concerns. The project concluded in a \$2M investment to re-source heat treating to AAM facilities.

Thesis Advisor: Thomas W. Eagar

Title: Thomas Lord Professor of Materials Engineering and Engineering Systems

Thesis Advisor: Stephen C. Graves

Title: Abraham J. Siegel Professor of Management and Engineering Systems

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## **NOTE ON PROPRIETARY INFORMATION**

In order to protect proprietary information, the data presented throughout this thesis has been altered and does not represent the actual values used by American Axle and Manufacturing, Inc. The dollar values have been disguised in order to protect competitive information.

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# 1. Introduction

American Axle & Manufacturing, Inc. (AAM) is an automotive supplier, which manufactures driveline and chassis systems and components for light trucks, passenger cars and sport utility vehicles. AAM provides systems or components to Original Equipment Manufacturers, tier-one and tier-two automotive suppliers [American Axle & Manufacturing, 2004]. In order to meet these needs, AAM is organized into two product divisions: the Driveline Division and the Metal Formed Products Division. The Driveline Division generates the majority of AAM's revenue through the manufacturing of: front axles, rear axles, differentials, drive shafts, crankshafts, steering and suspension systems and integrated modules and systems. The Metal Formed Products Division generates revenue through the forging and machining of automotive components [American Axle and Manufacturing, 2004]. This challenging automotive supply market dictates a constant focus on improving operations.

The objective of this thesis is to improve the product flow of AAM Metal Formed Products (MFP) Division's supply chain. The proposed approach utilizes process flow mapping to highlight current inefficiencies and potential opportunities for improvement. This thesis develops an approach to determine which manufacturing processes to re-source internally and makes recommendations on how to proceed. The framework of this thesis describes a process for making sourcing decisions for manufacturing processes.

*“One of the most fundamental strategic decisions every company faces is which activities should be conducted in-house and which should be “outsourced” from various partners and suppliers.”*

*[Hayes et al., 2005]*

This very critical decision has implications on the company's business model as well as the supply chain. A number of factors can lead a company to outsource manufacturing processes. As a result of this outsourcing, the supply chain can become very complex and difficult to manage. This thesis will look at this situation from the perspective of one manufacturer. The author will look at the conditions which led to the end state and make recommendations to develop an overall “lean” supply chain.

## **1.1 Thesis Motivation**

The MFP Division currently has a number of challenges: increasing steel prices, fixed labor costs, and declining sales. Steel is the largest component of unit cost for all the products within the division, accounting for over 50% of the cost of goods sold. These current business conditions have placed a tremendous strain on forging operations worldwide. With steel prices increasing by over 50% over the past 18 months, the raw material purchases have far exceeded expectations. In addition to increasing costs, the MFP Division has been challenged with declining sales. A waning top line coupled with United Auto Workers (UAW) labor contracts have led to excessive lay-off costs. In addition to excess labor, there is also excess capacity throughout the division in the form of floor space and machine capacity.

These issues forced senior management to take a hard look at the MFP Division and develop a plan to improve divisional operations. As a part of this plan, MFP Division's senior management wanted a thorough look at all of the manufacturing processes performed by the division both internally and by outside suppliers. In addition to identifying the processes and suppliers, senior management wanted to highlight opportunities for improving the process flow through re-sourcing manufacturing processes internally. This request initiated the thesis project. The overall project requirements were to map all material process flows, highlight the best opportunities to re-source, highlight alternatives, evaluate alternatives, and make recommendations to senior management. These improvements would increase gross margins through reduced inventory and freight while utilizing laid-off employees and surplus building space. The challenge was determining which manufacturing processes made both strategic and financial sense to re-source.

## **1.2 Thesis Overview**

The author utilizes process flow mapping techniques, basic inventory theory, lean manufacturing theory, strategic sourcing analysis and make/buy analysis. Process flow mapping was performed as a data collection method to highlight both visually and analytically the best opportunities to re-source. Inventory concepts were used to develop simplified tools for valuing inventory

reductions at a divisional level. The remaining techniques and theories helped to develop a divisional strategy for the sourcing of heat treating processes.

This project was the first study that focused on the divisional process flows. The author developed process flow maps for the entire division and all expenses associated with the supply chain. Next, the project highlighted all the manufacturing processes that were potential opportunities for re-sourcing to AAM facilities. The focus of the project then turned to the re-sourcing of the heat treating processes within the division. This thesis will spotlight a case study on applying a sourcing strategy to heat treating processes and conclude with a recommendation of a \$2 million capital investment. An overview of this project is provided in Figure 1.

<b>Project Overview</b>			
<b>Phase</b>	<b>1</b>	<b>2</b>	<b>3</b>
<b>Objective</b>	Analyze the supply chain	Identify re-sourcing opportunities	Analyze opportunities and recommendations
<b>Focus Areas</b>	All manufacturing processes	Heat treating processes	Carburizing processes
<b>Tools</b>	<ul style="list-style-type: none"> <li>• Process flow mapping</li> <li>• Inventory theory</li> <li>• Lean manufacturing</li> </ul>	<ul style="list-style-type: none"> <li>• Strategic sourcing analysis</li> </ul>	<ul style="list-style-type: none"> <li>• Make/buy analysis</li> <li>• Financial analysis</li> </ul>

**Figure 1: Project overview**

The key discoveries and outcomes from this project were:

- Process flow maps provide valuable visual tools for senior management.
- Process flow mapping provides a great tool for highlighting re-sourcing opportunities. It provides the data for financial analysis as well as a visual tool to identify and illustrate multiple alternatives.
- Process flow mapping highlights gaps in communication within the division, company and entire enterprise.
- Supply chain design should not be the product of a series of make/buy analyses. These sourcing decisions need to take into account strategic and market factors to help construct a supply chain that becomes a competitive advantage.
- Sourcing decisions must be made within the context of the company’s overall sourcing strategy. This strategy should take into account market factors and clearly state the overall company objective.

- The company's sourcing objective needs to be clearly communicated throughout the organization. There needs to be alignment between corporate senior management and each plant.
- In spite of current outsourcing trends, insourcing strategically important manufacturing processes can be financially justified as well as provide a competitive advantage.

### **1.3 Thesis Outline**

This thesis is organized into seven chapters:

*Chapter 1:* An overview of the thesis, company and academic relevance, research approach, results, conclusions and recommendations.

*Chapter 2:* This chapter will cover the project setting. It highlights relevant company history and organizational structure, current process capabilities, competitive landscape, forging trends, supply chain evolution and project problem statement.

*Chapter 3:* Discussion of process flow mapping, sourcing strategies, vertical integration, make versus buy analysis, and lean manufacturing concepts related to supply chain design.

*Chapter 4:* This chapter proposes a framework for re-sourcing heat treating processes to MFP Division's facilities.

*Chapter 5:* Contains a detailed analysis of the MFP Division process flows. This chapter provides both a visual representation and financial representation of the MFP Division's supply chain.

*Chapter 6:* Presents a discussion of the relevant strategic and market factors for AAM when making sourcing decisions for heat treating processes. The discussion is followed by a case study evaluating the re-sourcing of heat treating processes to AAM facilities.

*Chapter 7:* The thesis closes with conclusions, recommendations, and potential areas for future work.

## **2. AAM and MFP Division Overview**

This chapter provides a context for the project. In order to better understand the problem statement, this chapter highlights relevant company history and goals. It also describes the current process capabilities, competitive landscape and organizational committees. Most importantly, this chapter describes the division's current supply chain structure and its evolution over the past ten years.

### **2.1 Company Background**

American Axle and Manufacturing, Inc (AAM) was founded in 1994 by Richard F. Dauch, the current CEO, and partners. AAM's goal is to be the "world leader in the design, engineering and manufacture of driveline systems, chassis systems and forged products and services for light to heavy trucks, buses, sport utility vehicles and passenger cars" [American Axle and Manufacturing, 2004]. In order to achieve this goal, AAM provides a number of value added processes and services. During a meeting with the author on October 4, 2004, Mr. Dauch stated that AAM's core capabilities are:

1. Engineering
2. Forging
3. Heat Treating
4. Machining
5. Welding
6. Assembly
7. System Integration

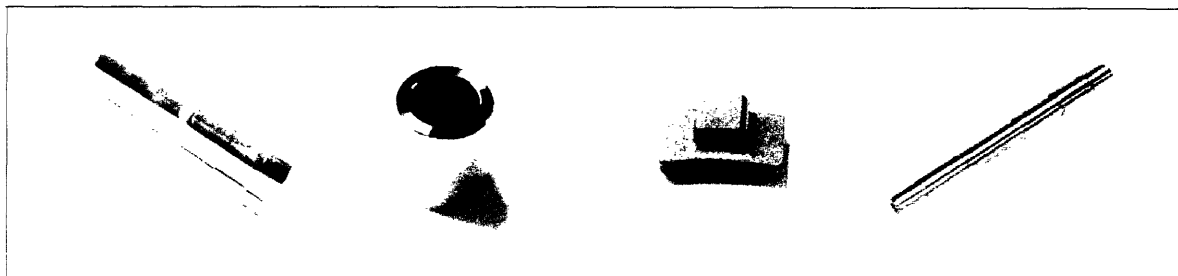
### **2.2 Metal Formed Products Division Background**

The division consists of six plants in North America: Cheektowaga Machining Facility (Cheektowaga, New York), Colfor Manufacturing (Malvern, OH), Detroit Forge Facility (Detroit, MI), Guanajuato Forge Facility (Guanajuato, Mexico), MSP Industries (Oxford, MI) and Tonawanda Forge Facility (Tonawanda, New York). When AAM was first founded, Detroit Forge and Tonawanda Forge were the only forging operations within the company. Later AAM acquired Colfor Manufacturing and MSP Industries and also built Cheektowaga and Guanajuato

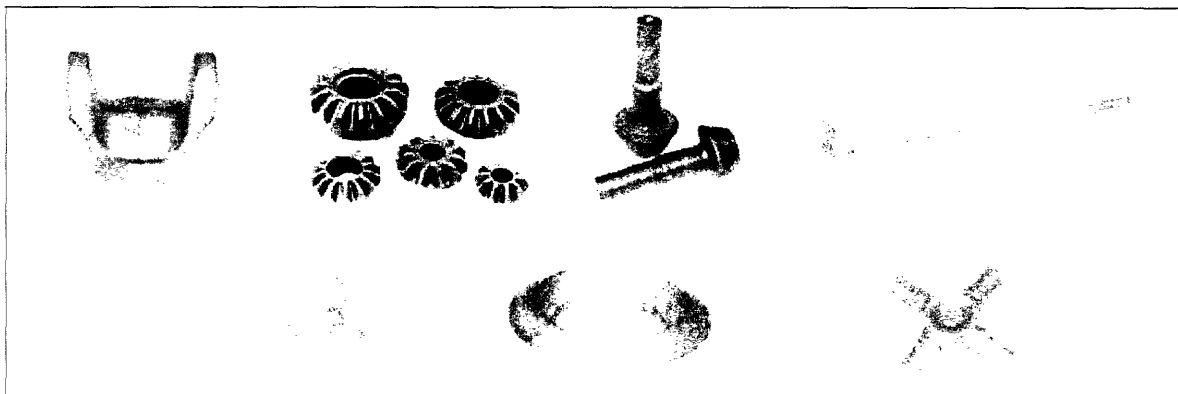
Forge. These plants employ over 3,000 hourly employees, most of which are represented by either the United Auto Workers (UAW) or International Association of Machinist (IAM).

These plants collectively make over 600 different parts within four major product categories.

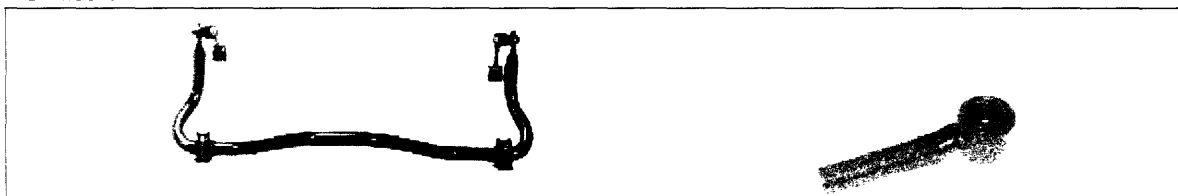
#### Transmission/Transfer Case



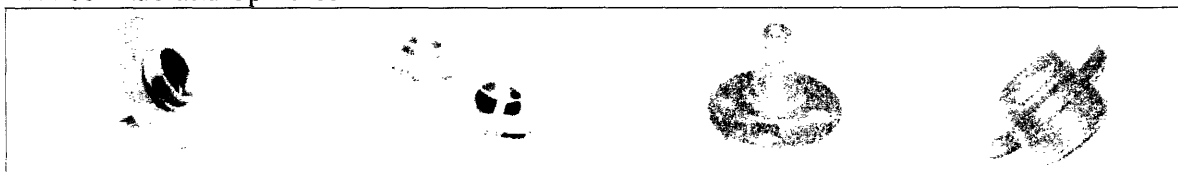
#### Axle and Driveline



#### Chassis



#### Wheel Hub and Spindles



**Table 1: MFP Division's product portfolio**



This collection of products requires a diverse set of processes and capabilities for production. Of the core company's processes, the MFP Division has primary responsibility within AAM for forging, machining and heat treating with a shared responsibility for engineering. Each of the core processes can be further divided into a specific type of process. For example, carburizing is a specific type of heat treating. Each of these types requires various equipment and technical capabilities.

### 2.3 MFP Division's Current Supply Chain Design

The products, processes, and acquisitions each paint a picture of why Metal Formed Products Division's supply chain is what it is today. Individually, each of these aspects drives the development of the supply chain structure in a logical manner. But when you look at these areas collectively, the supply chain has evolved into a complex web of suppliers, plants and customers (as seen in Figure 2).

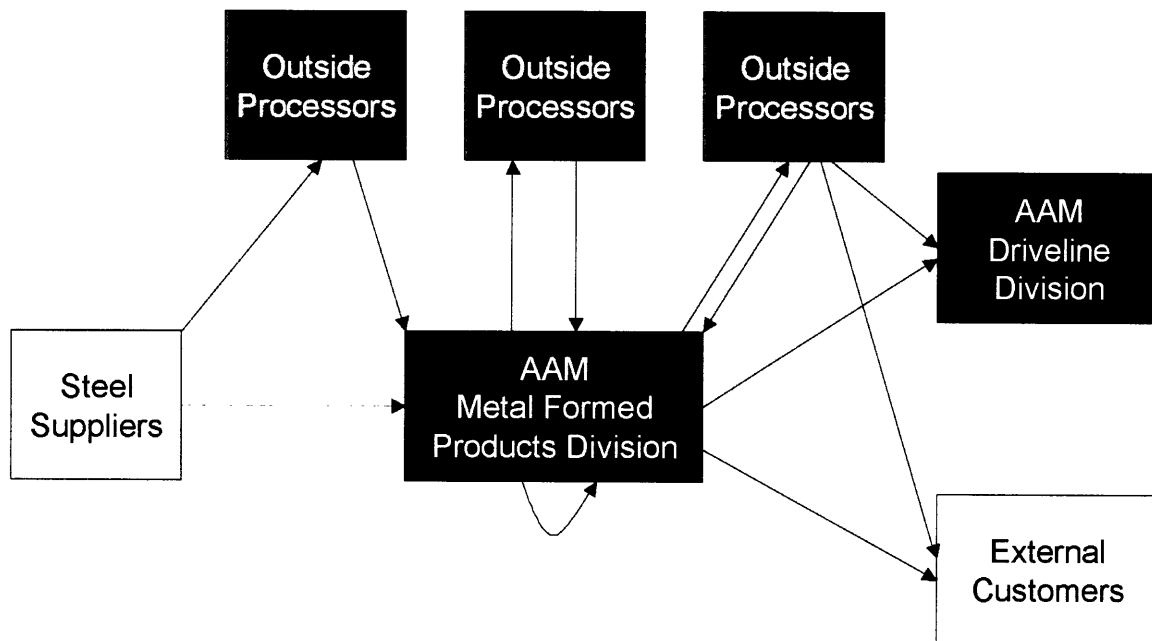


Figure 2: High level view of MFP Division's current supply chain

The large and diverse set of products requiring various types of processes forces MFP Division to quote new business using process capabilities from outside suppliers. Consider the following example. Though heat treating is considered a core capability, MFP Division does not possess

an extensive line of heat treating capability. Most new business will be quoted using outside heat treating capability to gain a more competitive price. The result is a set of outside process suppliers considered manageable by each plant within the division.

In 1999, AAM acquired both Colfor Manufacturing and MSP Industries. With any acquisition, management expects benefits through integration and identification of synergies. Despite AAM quickly moving to transfer product to better utilize their new capabilities, there are still other areas for further integration after the acquisitions. In particular, there are opportunities to share machining and heat treating capabilities or leverage outside processor spending for these capabilities.

A divisional look at the MFP Division's supply chain paints a much different picture than when the company was founded in 1994. Ten years later, the division is made up of 6 plants using nearly 50 outside suppliers providing saw cutting, machining, painting and heat treating capabilities with numerous raw material suppliers and customers.

## **2.4 AAM Goals and Automotive Component Market Trends**

As with any company, American Axle & Manufacturing sets goals. These goals drive corporate strategy which in-turn drive business decisions. Two of AAM's goals have implications on the sourcing of manufacturing processes and supply chain design. These noteworthy goals stated in the 2003 Annual Report are:

*Goal 1:* "Continue to diversify our customer base by reducing our reliance on sales to General Motors."

*Goal 2:* "Continue to increase our value-added content-per-vehicle by providing technologically advanced machining and assembly of powertrain components."

[American Axle & Manufacturing, 2003]

The goal of customer diversification has driven AAM since the company's inception. In addition to maintaining and growing the relationships with domestic Original Equipment Manufacturers (OEM), AAM has focused on becoming an automobile supplier for the Asian OEMs. In general, AAM MFP Division has had trouble breaking into this market. Research

shows that Asian OEM's source components to suppliers who have complete control over the cost and quality of their processes [Womack et al., 1991]. The MFP Division's supply chain structure made it difficult to convince potential Asian partners that the MFP Division has control over all of its processes.

During an interview with the author on December 1, 2004, the MFP Division's Director of Sales was asked what Asian partners think about having outside suppliers for heat treating, he said, "They hate it. They want to visit each of our external heat treating suppliers." Research supports this comment both in theory and in practice. Benchmarking Ohio Star Forge and Louisville Forge capabilities, suppliers to Toyota and Honda respectively, shows that each possess the internal manufacturing capabilities to allow for an end-to-end process flow [Ohio Star Forge, 2004 and Louisville Forge, 2004]. In particular, they maintain internal saw cutting and heat treating capabilities.

The second goal focuses on current market trends in the automotive supplier market. As AAM's annual report suggests, automotive OEMs are outsourcing more value added machining to tier-one and tier-two suppliers [American Axle and Manufacturing, 2003]. Machining is a downstream activity in AAM MFP Division's supply chain, but an upstream activity for AAM Driveline Division's supply chain. This activity presents an opportunity for AAM to increase content in driveline components through vertical integration.

## **2.5 AAM Sourcing Committee**

AAM's senior management supports re-sourcing of manufacturing processes to MFP Division facilities. During an interview on December 1, 2004 with AAM's Director of Capacity planning, he stated that "AAM believes that it should make any component or perform any manufacturing process that it can do cheaper." In general, AAM believes its core capabilities are all activities from raw steel to assembled driveline components.

Though the corporate default is to perform activities in-house, AAM's purchasing department had a make/buy committee to evaluate the options. The decision authority is the Vice President of Purchasing. Given the size and scope of the company, this structure translated into numerous

low dollar decisions at an executive level. The process was unmanageable and led to an increase in outsourced components and processes. In 2003, AAM identified this problem and highlighted the general opportunity of insourcing certain components and manufacturing processes.

In order to capitalize on this opportunity, AAM put together an “Insourcing Opportunity Team.” This team acts as the step between the person wanting to insource and the final approval authority (i.e. Vice President of Purchasing or Executive Vice President of Operations and Planning). The team is led by a director with the size of the team dependent upon the number of potential insourcing projects. This team is a new way of thinking because it provides a group that is responsible for insourcing decisions. This group is responsible for identifying and evaluating potential insourcing opportunities. Though the group is new, it does not require any new systems to aid in the evaluations.

The Insourcing Opportunity Team considers three major areas when assessing a proposed project. They are sales (or savings), capital expenditure and employed labor. The ratio of capital expenditure to annual sales (or savings) is an initial filter to prioritize the work. Once projects are selected for further evaluation, a project team performs a detailed study. The project team will determine manufacturing location and costs. Since its inception, the Insourcing Opportunity Team identified over \$55M of annual outside spending as potential insourcing opportunities. After the initial filter, the team recommended \$18M in annual outside spending for further evaluation. The team’s work resulted in insourcing a number of components and processes, reducing the annual spending at outside suppliers by \$9M.

This Insourcing Opportunity Team provides an avenue to attack some of the MFP Division’s problems and identify opportunities highlighted in sections 2.2 through 2.4. Despite the team’s best efforts, the MFP Division continues to outsource a number of key manufacturing processes. Since projects are initiated at the plant level, a number of potential synergies at the divisional level have been overlooked.

## 2.6 Problem Statement

*“Supply chain design is too important to leave to chance” [Fine, 1998]*

A number of factors and conditions led to the MFP Division’s current state. The supply chain evolution, company goals, market trends and corporate direction provide reasons to explore the possibility of re-sourcing manufacturing processes. The overriding goal is to reduce total costs in the supply chain while improving the operational efficiency of the division.

This goal can be obtained through improving the process flow by re-sourcing manufacturing processes (in particular the heat treating processes) throughout the entire MFP Division. These improvements would increase gross margins through reduced inventory and freight while hopefully utilizing laid-off employees and excess building space. The challenge is identifying the manufacturing processes that are both strategically and financially justified for re-sourcing.

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### 3. Literature Review

American Axle and Manufacturing prides itself on being a global manufacturing leader utilizing lean manufacturing techniques [American Axle and Manufacturing, 2005]. The principles of lean manufacturing drove the development of this project with the overriding objective of reducing costs within the supply chain.

This chapter reviews a few of the major concepts of lean manufacturing. In particular, it will focus on the seven commonly accepted wastes as well as a suite of tools used to identify them. It also describes factors to be considered when making strategic sourcing and vertical integration decisions. The chapter concludes with a discussion of current frameworks for evaluating a company's supply chain.

#### 3.1 Lean Manufacturing

Many companies attempt to develop a culture of identifying and removing waste in order to create flow in the system. Waste can be defined as any non-value adding activity. The seven commonly accepted wastes are [Womack and Jones, 1996]:

1. *Overproduction* – additional production of products that do not have customers
2. *Waiting* – products not being worked on and associates not being utilized
3. *Unnecessary Transportation* – additional movements of products which could be eliminated through a well-designed process flow
4. *Inappropriate Processing* – unnecessary steps in the process flow
5. *Unnecessary Inventory* – material or products in excess of what is needed to meet customer demand
6. *Unnecessary Motion* – requiring operators to move too much during the production process
7. *Defects* – problems with products which lead to scrap or rework

These wastes create the foundation for this project work. As mentioned in a previous section, AAM's Metal Formed Products Division's supply chain has evolved into a complex web of the MFP Division's plants, material suppliers, process suppliers and customers. This supply chain is littered with wastes that could be removed through a better supply chain design. A proper design of the division's supply chain will enable the elimination the following wastes: waiting, unnecessary transportation, inappropriate processing and unnecessary inventory.

## 3.2 Process Flow Mapping

Process flow mapping, which some people call value stream mapping, aims to better understand how all of the pieces of a manufacturing system fit together. There is extensive research in mapping the process flow or value stream with the overall objective of identifying opportunities for operational improvement in manufacturing organizations.

In his article “Learning to see: How does your supply chain function?”, Wood describes the use of five different analytical tools to determine how best to eliminate waste from a value chain [2004]. These tools have roots in many different fields from engineering and logistics to operations management. They are:

- *Process Activity Mapping* – this tool utilizes different techniques to collect information on operations, inspections, transportation and delays. The overall goal is to develop solutions to reduce waste by eliminating activities that are unnecessary, or simplifying the process through combining or reordering processes.
- *Quality Filter Mapping* – this approach classifies quality defects into three different categories. Each type of defect is then mapped on the supply chain to highlight problem areas and potential improvement opportunities.
- *Demand Amplification Mapping* – a mapping tool used to analyze the increased amplification of demand upstream in the supply chain.
- *Big Picture Map* – maps a product’s path from raw material to customer delivery, providing a visual representation of every process and the material information flows.
- *Four Fields Map* – a diagnostic tool that creates a fact-based map of a process with a focus on the informational flows.



In addition to highlighting the tools available for value stream mapping and waste elimination, Wood developed a decision support mechanism to determine the most appropriate tool or tools. The following table highlights the correlation of the tool with the type of waste and usefulness.

Type of Waste	Process Activity Mapping	Quality Filter Mapping	Demand Amplification Mapping	Big Picture Map	Four Fields Map
Overproduction	L		M		
Waiting	L		M	M	H
Unnecessary Transportation	H			M	
Inappropriate processing	H	L		M	H
Unnecessary inventory	M		H	M	
Unnecessary motion	H			M	
Defects	L	H		M	H

Legend:

H = High correlation and usefulness

M = Medium correlation and usefulness

L = Low correlation and usefulness

**Table 2: Value stream mapping tools [Wood, 2004]**

The project’s focus is improving operational efficiency through decreasing waiting, unnecessary transportation, inappropriate processing and unnecessary inventory. Based upon this decision support tool, the most appropriate techniques for evaluating the MFP Division’s supply chain are process activity mapping and big picture mapping. The big picture map provides a tool to visualize the entire process flow to help make decisions about improving the flow apparent to senior managers. Wood states that after an overall view of the value stream has been established through the big picture map, it may be necessary to obtain a more detailed view of the elements of the process through a process activity map.

The overall benefits of combining these two tools are identifying and mapping the product process flows well as collecting relevant quantitative data to support future analysis. More recent literature involves integrating these approaches at all levels of the enterprise. One such book is “Learning to See” by Shook and Rother.

Shook and Rother define a *value stream* as “all the actions currently required to bring a product through the main flows essential to every product” [Rother and Shook, 1999]. They focus on the production flow from raw material into the arms of the customers. Similar to Big Picture Mapping, they postulate that by taking the value stream perspective, one can focus on the entire picture in an effort to improve the whole, not just the individual processes.

Value stream maps can be a communication tool, a business planning tool and a tool to manage your change process [Rother and Shook, 1999]. It provides a tool to improve the value stream at a high level and on the shop floor. Value stream mapping involves a series of steps that identify product families, map the current state, identify the future state and develop a work plan to reach the future state. Overall, value stream mapping “forms the basis of an implementation plan by helping you design how the whole door-to-door flow should operate” [Rother and Shook, 1999].

This project was developed to look at the division’s overall supply chain design and develop ways to improve the process flows. Research shows that process flow mapping is a valuable tool providing both the visual and analytical information. Based on this, process flow mapping will be the foundation for developing a plan to design and implement changes to MFP Division’s supply chain.

### **3.2.1 American Axle & Manufacturing Tonawanda Forge Facility**

In his thesis, Steve King used value stream mapping to improve the operational flow of ring gears through Tonawanda Forge by looking at the extended value stream. King defined a variant of value stream mapping called hybrid value stream mapping that directly observes “the flows of information and materials as they occur in the entire manufacturing system, summarizing them visually, and then envisioning a future state with improved performance” [2004]. He used the resulting value stream map to identify and analyze potential improvement activities.

Through the value stream mapping exercise, King identified a couple of outside processing activities that prevented continuous flow. These outside processes are an extreme case of *process villages*. Womack and Jones describe *process villages* in their book “Lean Thinking.” They state “these *process villages* usually run in batch mode with long intervals between change-

overs” [Womack and Jones, 1996]. This practice creates excess inventory and reshipment to the next process step. King highlights these two wastes in his description of the current state. In particular, he identifies over 1000 miles of additional travel required by the practice of *process villages*.

In addition to identifying the problems caused by the outside processor, King used the results of value stream mapping to recommend the re-sourcing of certain manufacturing processes. He recommended re-sourcing billet preparation (i.e. saw cutting of steel bars) to a local plant or investing in saws, which would bring this outside processing into Tonawanda Forge. King also suggested utilizing an integrated annealing process with a ring-rolling forging press to eliminate the outside heat treating process of isothermal annealing. This proven technology will “slow-cool” the ring gears and eliminate the need to have a separate annealing process, significantly reducing transportation and allowing for continuous flow. These recommendations were later approved by AAM’s Board of Directors and are currently under development.

### **3.2.2 Medtronic’s Medical – Devices Facility**

Medtronic’s Xomed plant used value stream mapping to identify, analyze and implement manufacturing improvements. Medtronic manufactures products for ear, nose, throat and eye surgery [McClenahan, 2002]. The current operations produced product in a batch-and-queue fashion with long lead times. The use of value stream mapping reduced the lead times by over 50% in three years.

Value stream mapping was used both as a tactical and a strategic tool. Through mapping individual product lines, management identified bottlenecks and other production problems. From a strategic perspective, management combined the individual product line maps to make a map of the entire plant’s flow. This map showed that the “process of sterilizing products – whether done at the plant or off-site – constitutes a facility-wide bottleneck” [McClenahan, 2002]. Mapping the high-level process flows of all Medtronic’s product lines highlighted the importance of eliminating *process islands*.

### 3.3 Sourcing Strategy for Manufacturing Processes

As highlighted in this thesis, there are a number of different tools to identify and analyze waste in the value chain. The research suggests that process flow mapping provides visual and analytical support to identify processes that need to be evaluated as potential re-sourcing candidates. Though process flow mapping both identifies these activities and provides the information required for analyzing them, a structured approach is needed for evaluation.

Most literature suggests that sourcing decisions, as well as vertical integration decisions, should be analyzed both strategically and economically. Fine et al., in their article “Rapid-Response Capability in Value-Chain Design,” state that the first step is to identify the elements of the value chain. In addition to standard financial or economic analysis, they developed the “strategic value assessment to add a qualitative component to the evaluation and decision-making process” [Fine et al., 2002]. Their model used five key criteria to aid in the strategic component of a sourcing decision. These five criteria are:

1. *Customer Importance* – sensitivity of the customer to the sourcing decision
2. *Technology Clockspeed* – rate of change in technology
3. *Competitive Position* – relative market position in cost, quality and availability
4. *Supply Base Capability* – number and capability of suppliers
5. *Architecture* – how integral or modular is the product or process

[Fine et al., 2002]

This qualitative model provides a tool to identify and assess the strategic importance of a particular sourcing decision. This analysis provides a piece to the overall decision-making process. The strategic analysis should be combined with the economic analysis to help classify products or processes. Figure 3 combines both the economic and strategic analyses:

<i>Strategic Value Assessment</i>	<i>High</i>	Potential for future leverage	Likely insourcing candidates
	<i>Low</i>	Likely outsourcing candidates	Potential to harvest assets
		<i>Low</i>	<i>High</i>
		<i>Economic Value Added</i>	

**Figure 3: Decision matrix for sourcing decisions [Fine et al., 2002]**

### 3.4 Vertical Integration

When making sourcing decisions for key components, functions or processes, the company must look at the impact made on the entire value chain. In particular, companies must face the tough vertical integration or disintegration decision. MFP Division's consideration of insourcing manufacturing processes is considered decision of vertical integration.

The manufacturing processes at AAM that are being considered for insourcing are either downstream, midstream, or upstream activities. Downstream activities are those processes closest to MFP Division's end user. For example, machining activities immediately before going to AAM's Driveline Division are MFP Division's downstream activities. Midstream activities are those processes that occur between two MFP Division processes/operations. For example, most heat treating activities occur between two consecutive internal processes. Upstream activities are those processes closest to the raw material sources. For example, outside suppliers saw cut steel bars into billets for the MFP Division. Overall, insourcing this type of manufacturing processes creates a more vertically integrated division, or in the case of downstream activities, a more vertically integrated company.

### 3.4.1 Factors in Making the Vertical Integration Decision

Beckman and Rosenfield suggest using four sets of factors when making the vertical integration decision [2005]. The four factors are: strategic factors, market factors, product and technology factors and economic factors. The following provides a summary of the four factors and corresponding sub-factors when making the vertical integration decision.

#### 1. Strategic Factors

- a. *Core capabilities* – customers value activities that are unique to the company. These capabilities may also include some essential, but not core, activities that the company chooses to keep in-house.
- b. *Access to capabilities* – short and long-term view on developing and maintaining both core and non-core capabilities.

#### 2. Market Factors

- a. *Market reliability* – supplier ability in the key areas of cost, quality and availability. Companies may choose to vertically integrate to gain control over these areas.
- b. *Aggregating demand* – facilities that can take on demand from multiple sites or customers can utilize economies of scale in production and better handle customer variability.
- c. *Market Structure* – consideration of market power and dependency risks.

#### 3. Product and Technology Factors

- a. *Access to technology* – balance between having control over integral or critical technology with utilizing current external technology.
- b. *Product architecture* – balance the integration of design and production with the benefits of modular product architecture.

#### 4. Economic Factors

- a. *Production and delivery costs* – consideration of the cost of producing and delivering the product (i.e. materials, labor, overhead, transportation, and inventory) compared with the outside purchase price.
- b. *Investment costs* – capital costs associated with the sourcing decision
- c. *Transaction costs* – cost of searching, contracting, controlling and re-contracting with suppliers.

#### **3.4.2 Vertical Integration Decision Making Process**

In addition to describing the factors that should be considered in the vertical integration decision, Beckman and Rosenfield suggest the following steps a five-step process [2005].

##### *1. Apply the core capabilities screen*

The goal of the first step is to identify which activities should be retained in-house, and which are potential candidates for outsourcing. The focus of the analysis should be on using the list of core and essential capabilities identified in the company's business strategy. These capabilities should be based on the company's current competencies as well as those new ones which the company wishes to pursue based on the company's strategy to pursue new markets. Torkkeli and Tuominen summarize this thought in the following matrix.

<b>Core competence</b>	New	<i>Premier plus 10</i>  What new core capabilities will we need to build to protect and extend our franchise in current markets?	<i>Mega-opportunities</i>  What new core competencies would we need to build to participate in the most exciting markets of the future?
	Existing	<i>Fill in the blanks</i>  What is the opportunity to improve our position in existing markets by better leveraging our existing core capabilities?	<i>White space</i>  What new products or services could we create by creatively redeploying or recombining our current core capabilities?
		Existing	New
		<b>Market</b>	

**Figure 4: Establishing a core capability agenda [Torkkeli and Tuominen, 2001]**

2. *Assess the industry context and dynamics to identifying opportunities*

This step should focus on the company's current value chain as well as the industry analysis. To assess the value chain, Beckman and Rosenfield suggest developing a flowchart with the following information:

- Number and size of each player at each stage of the value chain
- Types, frequency and volumes of transactions between players
- Ownership connections between players

One should note that the flowchart is similar in nature to a value stream map with additional industry information. The analysis should focus on the current processes, a current assessment of the weaknesses and opportunities in the value chain.



### *3. Identify alternative value chain structures*

After assessing the current value chain and identifying strategic and market opportunities, the company must determine where to focus its resources. The goal of this step is to determine practical options for acquiring, developing or shedding a capability.

### *4. Assess alternatives and choose one*

Perform an analysis assessing the performance of each alternative as well as its strategic contribution. Use both objective criteria and subjective inputs from management to develop an agreement on the appropriate direction of the company.

### *5. Implement*

Move ahead with chosen alternative, remaining aware of the cost targets to be achieved and the associated risks.

## **3.5 Literature Review Summary**

Past research and literature provide the methodology to analyze potential sourcing decisions. There are also abundant resources to evaluate and assess the appropriateness of tools and factors when considering these decisions. Depending upon the industry, company and supply chain structure, one needs to adapt these methods and tools to evaluate the given circumstance.

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## **4. Methodology for re-sourcing heat-treating processes**

*“Ongoing value-chain assessment and design at the corporate level have become a necessity.”*

[Fine et al., 2002]

The current financial and market difficulties facing the MFP Division forced management to analyze the current value chain. This divisional look at the value chain should not be viewed as a one-time event, but as a continual process. In order to facilitate this ongoing value chain assessment, this project developed a framework to perform this analysis.

### **4.1 Steps in the Vertical Integration Decision**

Using the structure provided by Beckman and Rosenfield, the author conducted the following analysis. These steps were adapted from Beckman and Rosenfield and modified to aid in the MFP Division’s sourcing decision. The steps are:

1. *Apply the core capabilities screen and identify potential new activities*
2. *Assess the current supply chain structures to identify sourcing opportunities*
3. *Identify optional supply chain structures based on strategic and market factors*
4. *Assess sourcing options and choose the best option*
5. *Implement the chosen option*

The tools and criteria covered in the literature review (namely process flow mapping, sourcing factors, and vertical integration factors) provide the structure for my analysis. The initial steps of the analysis focus on identifying and gathering information on all manufacturing processes within the division. During the later steps, the analysis turns to sourcing of only heat treating processes, in particular carburizing. The reduced scope is due to the amount of time and resources devoted to the project as well as senior management direction. The author

recommends further analysis of certain other manufacturing processes highlighted by process flow mapping.

## **4.2 Analysis for Insourcing Heat Treating Processes**

The work documented in this thesis was performed during a six-month internship in American Axle and Manufacturing's Metal Formed Products Division. The following text highlights each of the steps in the re-sourcing framework and the corresponding analysis.

### *Step 1 - Apply the core capabilities screen and identify potential new activities*

AAM is a manufacturing company. The company claims core capabilities in all activities from raw steel to assembled driveline components. AAM believes that it should make any components or perform any manufacturing processes in its core markets where it provides a financial advantage. This belief in core capabilities is initiated from management. During a one-on-one meeting with the author, the CEO stated that AAM's core capabilities are: Engineering, Forging, Heat Treating, Machining, Welding, Assembly, and System Integration. During numerous meetings, senior management gave direction to invest in each of these core capabilities.

In particular, senior management focused on investing in internal heat treating processes. Developing this heat treating capability provides AAM an avenue to improve operations and gain new business. This approach is consistent with Torkkeli and Tuominen's work on establishing the core competence agenda. Re-sourcing heat treating to MFP Division facilities allows AAM to both "protect and extend [its] current markets" and "improve [its] position in existing markets" [Torkkeli and Tuominen, 2001].

### *Step 2 - Assess the current supply chain structure and identify sourcing opportunities through process flow mapping*

The author uses process flow mapping to document and analyze the supply chain structure. This analysis will focus on all products, processes, suppliers, and customers across the division. The detailed discussion will be provided in the subsequent chapter.

*Step 3 - Identify optional supply chain structures based on strategic and market factors*

*Step 4 - Assess options and choose one based on the cost, quality and availability of each option as well as its strategic contribution*

In Chapter 6, the author states the market and strategic factors used for evaluation. Based on these factors and the results of the process flow mapping, options are identified and assessed.

*Step 5 - Implement the chosen option*

In Chapter 7, the author highlights the chosen option and current implementation status.

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## **5. Material Process Flow Mapping**

Process flow mapping is a technique to document and analyze the supply chain for a given product or set of products. This project did not focus on highlighting the detailed value and non-value-added activities within the plants, but presents a high-level picture of the division's supply chain. These process flow maps highlight the movement of the product as well as the raw material purchases, sales, inventory, transportation and spending on outside processes. The information collected during process flow mapping highlights the division's complex supply chain structure and the opportunities for re-sourcing work. It also provides data to identify and evaluate potential improvement opportunities.

AAM employees had previously mapped the individual value streams for select product families within each of the plants in the division. Therefore, the focus of this project was to drive strategic changes in the process flows, rather than the tactical level changes targeted through value stream mapping. This project also did not specifically address the information flows, but the author worked with corporate and MFP division materials staff to highlight the communication gaps and target improvements. The materials department will pursue improvements in August 2005 once the re-sourcing opportunities are fully identified and approved.

### **5.1 Process Flow Mapping Objectives**

Process flow mapping is step two of the re-sourcing framework described in Chapter 4. The aim of this analysis is to create process flow maps for each of the plants within the division. Given MFP Division management direction and requirements in the re-sourcing strategy, the mapping activity should fulfill the following objectives:

- Identify the process flows for all products in the MFP Division. This mapping should identify all of the stakeholders, processes and products. The stakeholders encompass the suppliers, internal and external processors and customers.
- Collect all outside processing expenses. These expenses are classified into three different categories: outside processing paid by MFP Division, outside processing paid by the Driveline Division on MFP Division products for MFP Division

processing, and value added outside processing expenses. The value added expenses include products sold to customers who then add value through additional processing and are then resold to the AAM Driveline Division.

- Collect all related outside processing expenses. The expenses include freight expenses and the additional inventory holding costs due to sending products to outside suppliers for processing.

The overall objective was to create a concise report of the MFP Division’s process flows to be used to develop alternatives for future supply chain design.

## 5.2 Mapping MFP Division’s Process Flows

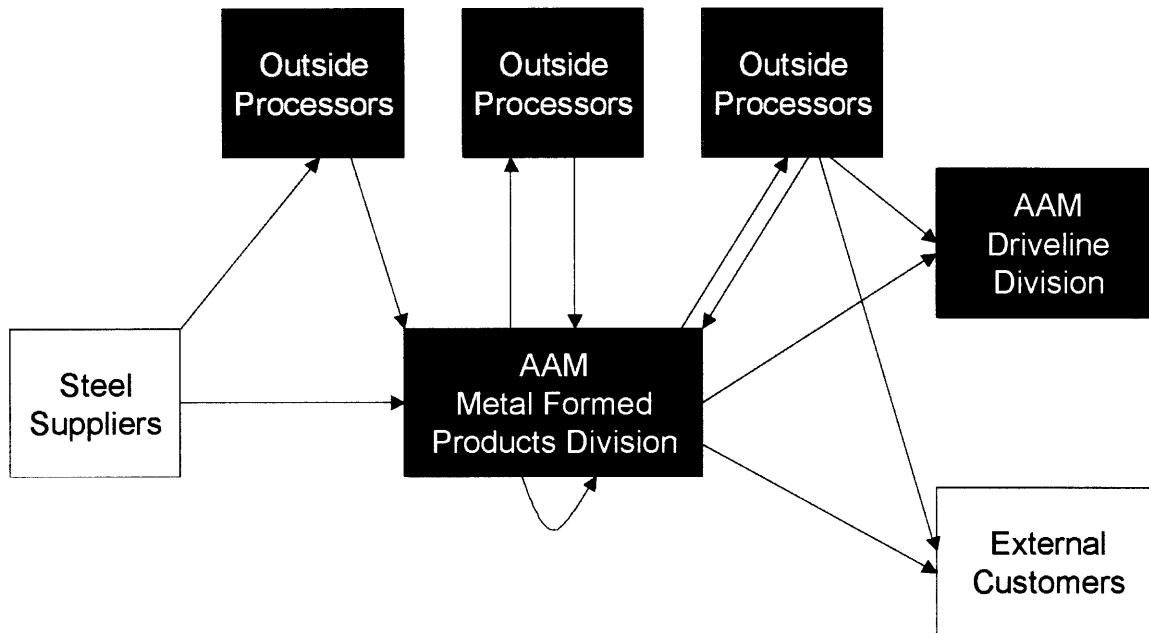
The MFP Division generates over \$500 million in annual revenues. The division produces over 650 different parts at an annual volume in excess of 124 million pieces (see Table 3). The products range from raw forgings to finished machined forgings. They also vary in size from 0.2 to 40 pounds.

	Number of Different Parts	Annual Piece Volume
Colfor Manufacturing	285	22M
Detroit Forge	135	13.5M
Guanajuato Forge	35	3M
Tonawanda Forge	110	48M
Cheektowaga	35	15.5M
MSP Industries	55	22.5M
<b>TOTAL</b>	<b>&gt; 655</b>	<b>&gt; 124.5M</b>

**Table 3: MFP Division's part & volume information (includes all discrete part numbers)**

The product flow of the MFP Division consists of a few basic processes: Cutting, Forging, Heat Treating, and Machining. Each of the basic processes may have a number of various internal steps depending upon the product’s requirements. To add to the complexity, different products may require a different process sequence. Though AAM claims core capability in each of the basic processes within the division, the various product specifications and the evolution of the MFP Division make it nearly impossible to maintain internal capability in each of the processes required for production. Therefore, a high-level view of the MFP Division’s supply chain shows the complexity (see Figure 5).





**Figure 5: High-level view of MFP Division's current supply chain**

The following narrative provides basic descriptions of various players and their value added processes. Order should not be implied since the sequence is driven by product specifications.

- *Steel Suppliers* – AAM is the largest consumer of Specialty Bar Quality (SBQ) Steel in North America. Over ten global steel suppliers currently provide SBQ to the MFP Division. Steel shipments are received in bundles of steel bars in bulk deliveries.
- *Outside Processors*
  - *Billet Preparation:* This step takes raw material from the steel mills and makes it capable of being forged. Depending upon the product requirements this can entail a number of different processes. The majority of the outside processing is the saw cutting of bars into billets primarily for plants without internal saw capability.

- *Heat Treating*: The heat treatment of steel is based on the physical metallurgical principles which relate processing, properties and structure [Davis, 1998]. Heat treatment is the heating and cooling of solid metal or alloy in such a way as to obtain desired material conditions or properties. The processing is most often entirely thermal and modifies only structure to enable forging or machining of a steel billet [Davis, 1998]. The following types of heat treatment are required by MFP Division's parts:
  - Annealing
  - Belt Annealing
  - Carburizing and Vacuum Carburizing
  - Isothermal Annealing
  - Normalizing
  - Quenching & Tempering
  - Spheroidize Annealing
  - Stress Relieving
  
- *Machining*: This process involves removing material from a metal part using a cutting tool, which is most often a powerdriven tool [Davis, 1998].
  
- *Shot Peening*: This process is cold working the metal surface by metal-shot impingement to harden the surface [Davis, 1998].
  
- *Miscellaneous Processes*: There are a few other processes that external suppliers provide for AAM. These processes include: painting, plating, phosphate or polymer coating, e-coating, welding, applying adhesive or inspecting.
  
- *Metal Formed Products Division's Internal Processing*: There are a number of core processes performed within the division. These processes include: shearing and saw cutting of steel bars, forging, heat treating, machining and phosphate coating.

- *Customers:* MFP Division's plants service both internal and external customers. The AAM Driveline Division makes up over 60% of the division's sales with the remainder going to OEM's, tier-one and tier-two suppliers.

## **5.3 Expense Information**

One of the objectives of the process flow mapping is to gather all necessary information required to accurately analyze all processes. In particular, the analysis focused on acquiring the financial information required to evaluate potential processes to re-source. This financial information includes the processing, freight and inventory expenses.

### **5.3.1 Processing Expenses**

The processing expenses represent the amount paid to the outside processor for the processes provided. These expenses are usually charged on a price-per-piece or price-per-pound basis depending upon the type of process. Due to AAM's organizational and supply chain design, these direct expenses can be classified into three different categories:

1. Expenses paid by MFP Division for MFP Division processes performed. These expenses include payment for processes such as saw cutting, heat treating and machining.
2. Expenses paid by Driveline Division for MFP Division processes performed. These expenses include the same processes as the first category but are paid by the Driveline Division due to the specified contract. This project attempted to capture all processes expenses required to deliver a product to the customer regardless of which AAM division was billed.
3. Products sold to an outside processor who performs a value-added service and sells the finished product to the Driveline Division. For example, a number of products are first sold to machine shops and then sold back to the Driveline Division.

Accounting for all these types of processing expenses, the total annual outside processing expense is approximately 10% to 15% of sales, which represents a significant portion of MFP

Division's costs of goods sold. The following table shows the percentage of the annual outside processing expenses in each of the major process categories by plant.

	Detroit Forge	Tonawanda Forge	MSP Industries	Guanajuato Forge	Colfor Manufacturing	Totals
Billet Prep	2.2%	1.3%				<b>3.5%</b>
Heat Treating	1%	6.7%	3%		4.4%	<b>15.1%</b>
Machining	26.4%	13.4%	13.4%	17.1%	5.7%	<b>76%</b>
Paint/Plate/Coat	3.9%	0.2%			0.1%	<b>4.2%</b>
Shot Peening	1%					<b>1%</b>
Other	0.1%	0.2%				<b>0.3%</b>
<b>Total</b>	<b>34.4%</b>	<b>21.8%</b>	<b>16.4%</b>	<b>17.1%</b>	<b>10.3%</b>	

**Table 4: MFP Division's outside processing expenses**

### 5.3.2 Freight and Inventory Holding Expenses

Freight expenses include transportation to and from the outside processor. These numbers represent actual freight expenses that occurred over the course of the year. MSP Industries does not contract out freight; they utilize their own trucks for transportation to and from outside processors. The freight costs were estimated based upon a rate of \$55/hour. Table 5 shows the percentage of the total annual freight expense in each of the major process categories by plant.

	Detroit Forge	Tonawanda Forge	MSP Industries	Guanajuato Forge	Colfor Manufacturing	Totals
Billet Prep	17.0%	5.0%				<b>22%</b>
Heat Treating	4.0%	18.0%	7.0%		5.0%	<b>34%</b>
Machining	8.0%	6.0%	1.0%	4.0%	1.0%	<b>20%</b>
Paint/Plate/Coat	16.0%	0.2%			1.0%	<b>17%</b>
Shot Peening	7.0%					<b>7%</b>
Other						<b>0%</b>
<b>Total</b>	<b>52%</b>	<b>29%</b>	<b>8%</b>	<b>4%</b>	<b>7%</b>	

**Table 5: MFP Division's outside processing freight expenses**

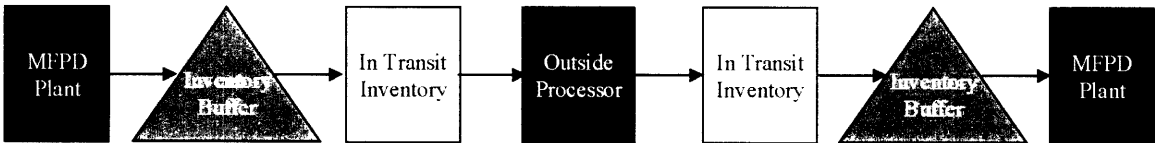
Outsourcing forces manufacturers to carry additional inventory. Depending upon which process is outsourced, both the manufacturer and supplier may carry additional inventory. A number of factors contribute to the amount of additional inventory in the supply chain. In particular, the process type, process cycle time, product volume and transportation frequency combine to drive the amount of additional inventory required in the supply chain.

In order to assess the amount of additional inventory in the system due to outside processing, value stream mapping suggests comparing the current value stream to the future value stream. Value stream mapping focuses on a specific product or product family; therefore, the assessment is based on a subset of the products that flow from the plant to the outside supplier. When looking at the divisional process flows, analysis should focus on all the products that flow from a plant to a specific outside process supplier. To accurately assess the additional inventory in the system, the author created a discrete set of supply chain structures representing current and potential inventory locations.

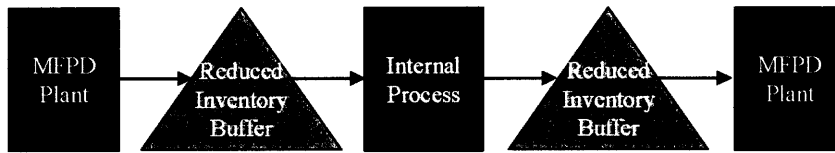
Within the Metal Formed Products Division, there are five major supply chain structures involving outside suppliers. These structures are:

1. *MFP Division Plant to Outside Supplier returning to MFP Division Plant*
2. *Steel Supplier to Outside Supplier then proceeding to MFP Division Plant*
3. *MFP Division Plant to Outside Supplier then proceeding to the Customer*
4. *MFP Division Plant to Outside Supplier to another Outside Supplier returning to MFP Division Plant*
5. *MFP Division Plant to Outside Supplier to another Outside Supplier proceeding to the Customer*

The following figures illustrate the current and future process flows for the first supply chain structure.



**Figure 6: Supply chain structure 1 - current**



**Figure 7: Supply chain structure 1 – future (once process is insourced)**

Since there are multiple products traveling each of these routes, the effort required a high-level assessment of the additional inventory carried due to the outside processors. Forging involves batch manufacturing, therefore, the major drivers in average inventory are the process type, the process cycle time and transportation frequency. The author used basic inventory theory to assess the impact comparing the outsourced to in-house processing. Using this comparison, one can determine a percentage reduction in inventory for each plant with each outside processor. After calculating the reduction, the following equation was used to determine the amount of additional inventory due to outside suppliers.

$$\% \text{ Reduction in Inventory} \times \text{Current On - hand Inventory} \times \% \text{ Annual Holding Cost}$$

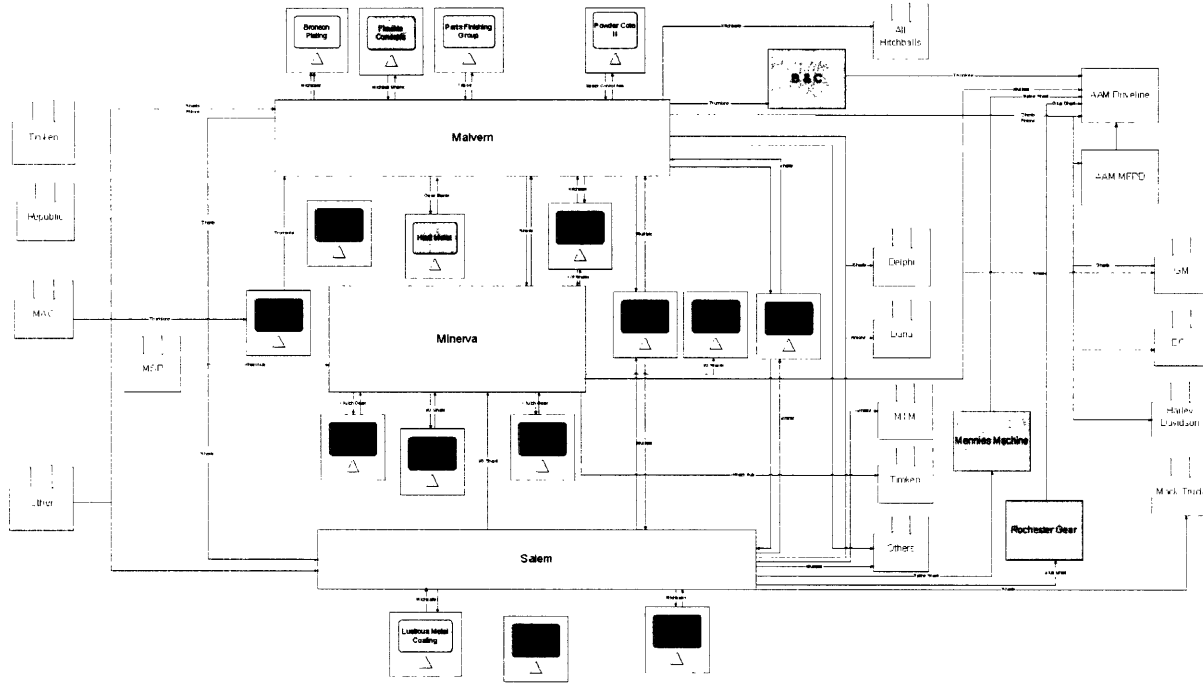
Table 6 highlights the percentage of the additional annual inventory expenses in each of the major process categories by plant:

	Detroit Forge	Tonawanda Forge	MSP Industries	Guanajuato Forge	Colfor Manufacturing	Totals
Billet Prep	11.3%	3.3%				<b>14.6%</b>
Heat Treating	2.7%	12.0%	4.7%		36.6%	<b>55.9%</b>
Machining	5.3%	4.0%	0.7%	2.7%	0.7%	<b>13.3%</b>
Paint/Plate/Coat	10.7%	0.1%			0.7%	<b>11.5%</b>
Shot Peening	4.7%					<b>4.7%</b>
Other						<b>0.0%</b>
<b>Total</b>	<b>34.6%</b>	<b>19.4%</b>	<b>5.3%</b>	<b>2.7%</b>	<b>37.9%</b>	

**Table 6: MFP Division's outside processing inventory expenses**

In addition to the information collected, detailed process flow maps were created for each plant within the division. These maps served as visual guides for highlighting potential re-sourcing areas within the supply chain. Figure 8 represents a process flow map of Colfor Manufacturing.

The remaining high-level process flow maps which can be found in Exhibits 1 to 6. For propriety reasons, the expenses and sales figures for each of the stakeholders within the map were withheld.



**Figure 8: Process flow map for Colfor Manufacturing (a legend can be found in Exhibit 1)**

### 5.4 Detailed Process Flow Example

In order to make specific sourcing decisions, the high-level process flow maps must be further broken down. Figure 9 provides a view of the current process flow for selected parts flowing through Colfor Manufacturing and Detroit Forge. This process flow highlights a number of wastes in the system; products travel in-and-out of MFP Division facilities resulting in excess inventory, waiting, handling and transportation. Exhibit 7 (in Chapter 8 - Exhibits) provides different perspective of the product flows on a physical map of the Midwest. Table 7 provides the accompanying expenses. The carburizing process highlighted in this process flow was selected for re-sourcing and will be discussed in further detail in Chapter 6.

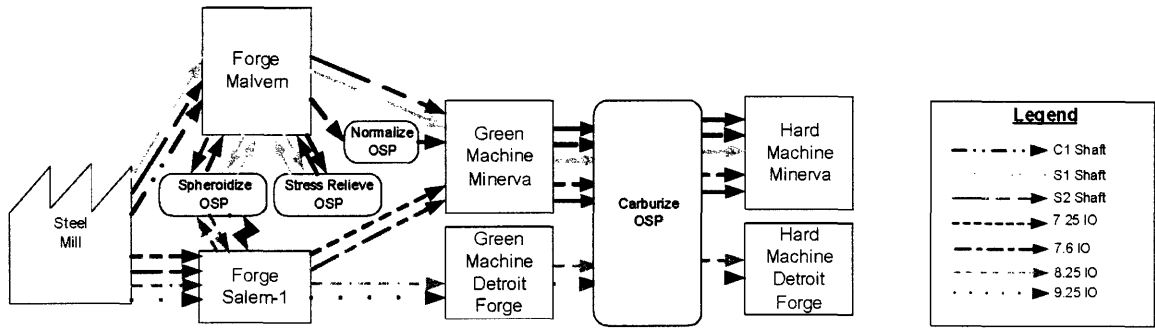


Figure 9: Current carburize part process flow

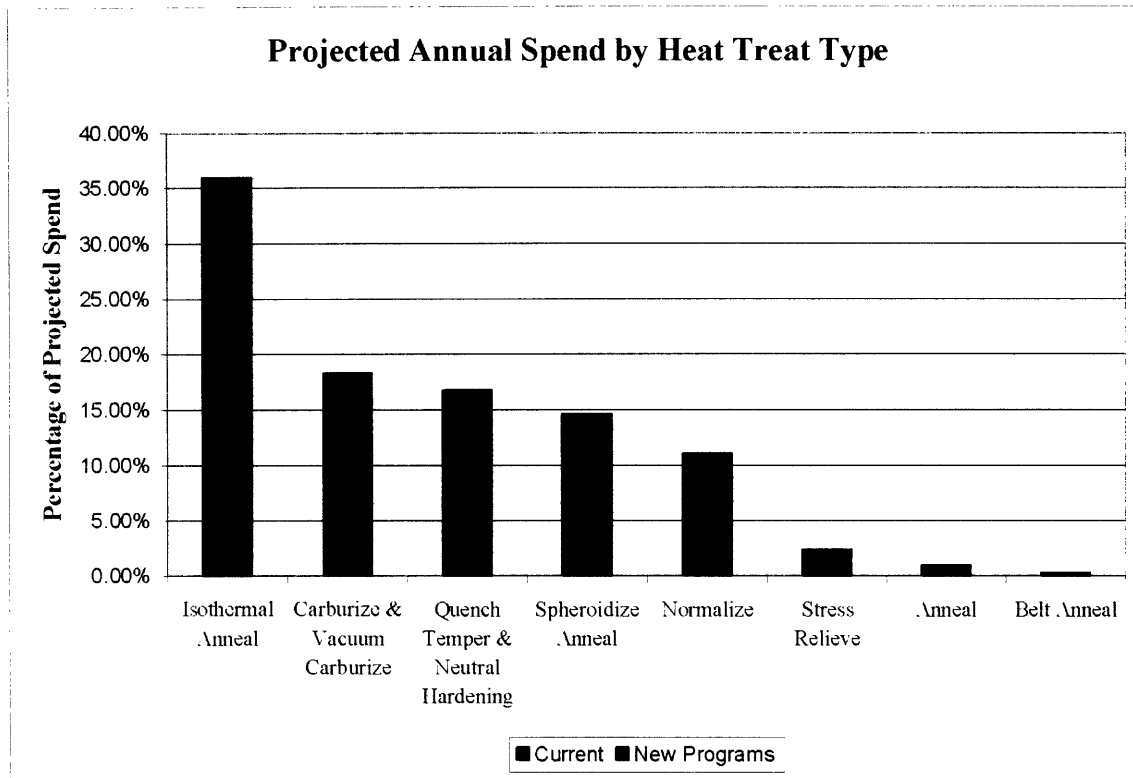
Type	Annual Expenses Due to Outside Processing
Processing	\$1.5M
Freight	\$100k
Inventory Holding	\$10k

Table 7: Current expenses due to outside processing for carburized parts

### 5.5 Target Re-sourcing Opportunities

The process flow maps and accompanying expense information highlight target areas to re-source to MFP Division Plants. Nearly 99% of the outside processing expenses take place within four areas: Billet Preparation, Heat Treating, Machining, and Painting/Plating/Coating. Three of these four categories are considered AAM core capabilities (e.g. saw cutting, heat treating and machining). Over the past year, MFP Division analyzed the investment in saw cutting within Detroit Forge and Tonawanda Forge and proceeded with the investment in these capabilities. The MFP Division is using the information from this project to evaluate the machining portion of the outside processing. Figure 10 shows the breakdown of where spending on outside processing for the different type of heat treating occurs. The graph distinguishes between current and new programs. Current programs represent the actual expenses paid on an annual basis while new programs represent the estimated annual expenses based on projected volumes.





**Figure 10: Percentage of projected annual spend by type of heat treatment**

Process flow mapping provided a tool to visually represent the complexity and inherent waste of the supply chain design. The accompanying data provided a consolidated view of divisional outside processor spending and additional expenses due to outside processing. Process flow mapping was the genesis for the studies on re-sourcing heat treating. Figure 10 illustrates that there are five target areas for further analysis:

- Isothermal Annealing
- Carburizing and Vacuum Carburizing
- Quench Temper and Neutral Hardening
- Spheroidize Annealing
- Normalizing

These areas will be explored in detail in the following chapter.

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## 6. Analyzing Heat Treating Processes Sourcing Alternatives

Process flow mapping highlighted the potential opportunities for improving the flow of products requiring heat treatment. In addition to visual representation of the complexity, process flow mapping identified all the expenses associated with outsourcing heat treating. This provides the data to financially evaluate the alternatives. In addition to economic impact, AAM must consider strategic or market factors in the analysis to help prioritize investments. This project developed a set of strategic and market factors to guide and prioritize the analysis.

### 6.1 Strategic and Market Factors

In order to determine which types of heat treatment might be re-sourced, the relevant market and strategic factors needed to be determined. Based on the MFP Division’s industry dynamics and the relevant research referenced in Chapter 3, the following factors were used in the evaluation.

- *Customer Preference* – the sourcing decision preferred by and the relative importance of this decision to the customer.
- *Supply Base Reliability* – supplier’s reliability and competitiveness in the key areas of cost, quality and capacity availability.
- *Supply Base Structure* – the number and long-term viability of the current supply base.

Table 8 provides the levels of evaluation and corresponding recommendation for each of the factors.

<b>Factor</b>	<b>Evaluation</b>	<b>Recommendation</b>
Customer Preference	High Importance	Insource
	Low Importance	Outsource
Supply Base Reliability	Unreliable & Noncompetitive	Insource
	Reliable & Competitive	Outsource
Supply Base Structure	Few & Unstable	Insource
	Numerous & Stable	Outsource

**Table 8: Strategic and market factors for sourcing evaluation**

### **6.1.1 Customer Preference Evaluation**

The customer preference should drive the MFP Division's sourcing decision. Based on research and experience in the forging market, the MFP Division realizes that Asian OEMs and affiliated tier-one suppliers primarily source work to suppliers with internal heat treating capability. Given the customer preference, an investment in internal heat treating capability provides an opportunity to grow sales outside of the current customer portfolio.

### **6.1.2 Supply Base Reliability Evaluation**

Suppliers must maintain quality, competitive cost structure and capacity availability. Currently, there are a number of cost concerns in the supply chain. A major supplier approached AAM about paying energy surcharges due to rising energy costs and threatened to stop shipments. This example highlights the concern of major players in the supply chain. There are a number of suppliers without significant leverage that should also concern AAM. There are two issues to consider for suppliers without significant leverage. First, these suppliers may absorb the increasing energy costs, creating issues about their long-term viability. Second, a number of small forging companies are facing financial hardships and are going out of business. Heat treatment suppliers count on this additional volume to amortize their costs. As volumes decrease, the costs to AAM will increase.

In addition to cost and quality as important factors to consider, capacity availability is a major driver in the entire supply chain. The MFP Division supplies AAM's Driveline Division with a number of key components. Problems upstream in the supply chain must be overcome as the product moves downstream. By owning the heat treating processes, the MFP Division can ensure capacity availability at all times. Developing and maintaining internal heat treating capability helps ensure performance through control of cost, quality and capacity availability.

### **6.1.3 Supply Base Structure Evaluation**

Outsourcing manufacturing is a risky venture. Despite the MFP Division having over ten heat treat outside processors, each specific type of heat treating has only a few different suppliers. For example, the heat treating supply base for carburizing components is very thin for the Michigan, New York and Ohio area. This practice of sourcing to a few suppliers with an arm's length relationship creates dependency risk. Though heat treating does not require specialized

assets, the lead time and capital for developing internal capability are extensive. All these factors create uncertainty in the supply base capability and a desire to insource certain types of heat treating.

#### **6.1.4 Other Factors for Consideration**

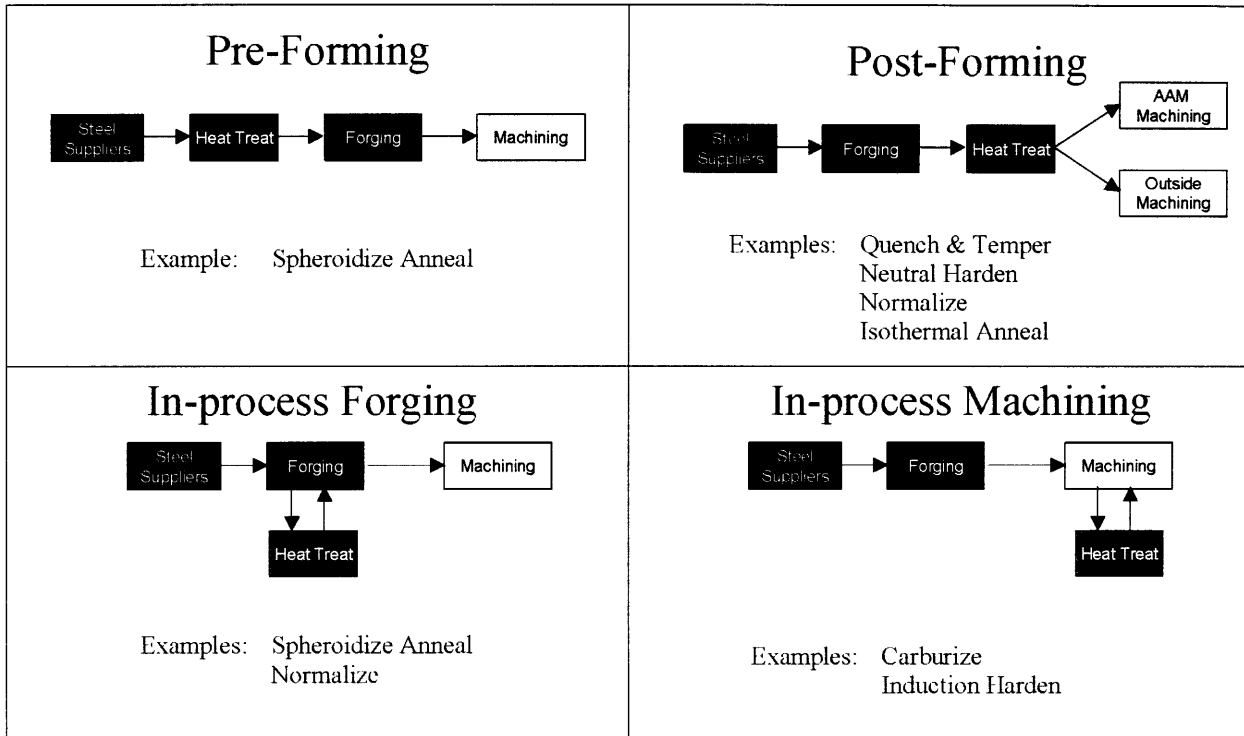
Though not specifically listed in the strategic and market factors, there are a few other factors considered in the sourcing decision. These factors demonstrate why other aspects were considered in addition to the structured analysis. The two additional factors for consideration are aggregating demand and competitors in the market.

First, AAM has an opportunity to aggregate demand across the division. Most companies outsource to utilize external economies of scale with suppliers and external product variability which allow suppliers to “right size” capacity for a number of customers [Beckman and Rosenfield, 2005]. AAM possesses the opportunity to aggregate demand internally. Since the acquisitions and the addition of the new plants, AAM has not aggregated demand to take advantage of economies of scale and product variability for heat treating processes.

Second, the MFP Division has a number of competitors in both the forging and machining market. Benchmarking competitors highlights the opportunity to create unique value in the marketplace by developing internal heat treating capability.

### **6.2 MFP Division’s Heat Treating Process Flow Scenarios**

Figure 11 depicts the different process flows involving heat treating as four distinct scenarios. It also lists examples of the different types of heat treatment that typically occur in each of the corresponding scenarios. These different scenarios provided a way to visually capture the strategic and market factors discussed in the previous section (i.e. Customer Preference, Supply Base Reliability, and Supply Base Structure). Aligning the strategic and market factors to each of the scenarios provided a tool to help prioritize the re-sourcing efforts.



**Figure 11: MFP Division's heat treating scenarios**

**6.2.1 Scenario 1 – Pre-Forming**

This scenario encompasses all heat treating that takes place prior to entering AAM facilities. For example, steel bars arrive at the outside processor. The bars are cut into billets then spheroidize annealed. The billets are shipped to AAM where they are forged into trunnions. In general, these types of processes provide very little market and strategic benefit since all activities take place prior to arriving at AAM facilities. In particular, it provides little value to the customer and does not provide control of downstream capacity availability. Therefore, the re-sourcing decision should be based purely upon the financial analysis. Table 9 summarizes the evaluation and recommendation for scenario 1.

<i>Scenario 1 – Pre-Forming</i>		
Factor	Evaluation	Recommendation
Customer Preference	Low importance	Outsource
Supply Base Reliability	Competitive in cost, quality and availability	Outsource
Supply Base Structure	Few but stable	Insource/Outsource
<b>Overall</b>		<b>Outsource</b>

**Table 9: Pre-Forming market & strategic evaluation summary**

### 6.2.2 Scenario 2 – Post-Forming

This scenario encompasses all heat treating that takes place after leaving MFP Division’s forging facilities. Once the products are heat treated, they are either shipped to AAM facilities or another outside processor for machining. For example, ring gears are forged at Tonawanda Forge, and then sent to an outsider processor to be isothermal annealed. After annealing they are shipped to the Driveline Division to be machined. Depending upon the machining source, these heat treating processes provide both market and strategic benefit. In particular, internal heat treating capability would provide more control over cost, quality and capacity availability. Control of capacity availability is a major concern when supplying commodity parts to the Driveline Division since AAM does not want any halts in axle production due to lack of supply of ring gears. Therefore, AAM should develop alternatives to re-source *post-forming* heat treating for parts later machined by AAM. Table 10 summarizes the evaluation and recommendation for scenario 2.

<i>Scenario 2 – Post-Forming</i>		
<b>Factor</b>	<b>Evaluation</b>	<b>Recommendation</b>
Customer Preference	High/Low	Insource/Outsource
Supply Base Reliability	Competitive in cost and quality; Concerns with capacity availability	Insource
Supply Base Structure	Few but stable	Insource/Outsource
<b>Overall</b>		<b>Insource</b> (if AAM machined) <b>Outsource</b> (if outside machined)

**Table 10: Post-Forming market & strategic evaluation summary**

### 6.2.3 Scenario 3 – In-Process Forging

This scenario encompasses all heat treating that takes place between two successive forging operations. The MFP Division produces a number of parts that require *in-process forging* heat treatment. For example, I.O. shafts are pre-forged in MFP Division facilities then sent to a heat treating supplier to be normalized. The shafts return to MFP Division facilities to be forged. The major market and strategic benefits of developing an internal heat treating capability are supplier base reliability and customer preference. Gaining control over costs, quality and capacity availability gain customer preference and improve operations. AAM must look at developing alternatives to re-source *in-process forging* to AAM facilities. Table 11 summarizes the evaluation and recommendation for scenario 3.

**Scenario 3 – In-Process Forging**

Factor	Evaluation	Recommendation
Customer Preference	High importance	Insource
Supply Base Reliability	Competitive in cost and quality; Concerns with capacity availability	Insource
Supply Base Structure	Few but stable	Insource/Outsource
<b>Overall</b>		<b>Insource</b>

**Table 11: In-Process forging market & strategic evaluation summary**

**6.2.4 Scenario 4 – In-Process Machining**

The last scenario covers all heat treating that takes place between two successive machining operations. This type of heat treating currently will become more prevalent as the MFP Division takes on more value-added machining. Transmission shafts provide a good example of this scenario. These shafts are green<sup>1</sup> machined, then sent to an outside heat treating supplier to carburize the shafts (i.e. harden the metal). Transmission shafts are returned to MFP Division facilities where they are hard<sup>2</sup> machined. Investing in internal heat treating capability for *in-process machining* provides the MFP Division with a capability desired by customers and control over the process. Table 12 summarizes the evaluation and recommendation for scenario 4.

**Scenario 4 – In-Process Machining**

Factor	Evaluation	Recommendation
Customer Preference	High importance	Insource
Supply Base Reliability	Competitive in cost and quality; Concerns with capacity availability	Insource
Supply Base Structure	One supplier but stable	Insource
<b>Overall</b>		<b>Insource</b>

**Table 12: In-Process machining market & strategic evaluation summary**

**6.2.5 Summary of Scenarios and Sourcing Target Processes**

Based on market and strategic factors, the target areas for re-sourcing are *in-process forging*, *in-process machining* and *post forming* for parts later machined at AAM. These areas will help

<sup>1</sup> Green machining is the machining of a part prior to heat treating. This type of machining is also known as rough machining.

<sup>2</sup> Hard machining is the machining of a part after it is hardened by a heat treating process. It is also called finish machining.



improve MFP Division's competitive position through control of cost, quality and availability. Insourcing mid-stream processes will meet a customer preference that will help attract and gain new business. Lastly, bringing these types of processes in-house will reduce the risk associated with sourcing to outside suppliers.

### **6.3 Current Activity**

Process flow mapping highlighted the following five target areas for potential investment: Isothermal Annealing, Carburizing & Vacuum Carburizing, Quench Tempering & Neutral Hardening, Spheroidize Annealing and Normalizing. The author worked on preliminary business cases to re-source four of the five types of heat treating. The following will highlight the status of each of these target areas. Carburizing and Vacuum Carburizing were the focus of the project based on the market and strategic implications discussed in the previous section. A thorough analysis of re-sourcing carburizing and vacuum carburizing is presented in Section 6.4.

#### **6.3.1 Isothermal Annealing**

Outside processors isothermal anneal ring gears produced by Tonawanda Forge. During his LFM internship, Steve King recommended an integrated annealing process with a ring-rolling forging press to eliminate the isothermal annealing heat treating process [2004]. This investment will eliminate all isothermal annealing provided by outside suppliers. AAM is currently investing in this process improvement.

#### **6.3.2 Quench Temper and Neutral Hardening**

The majority of the quench temper and neutral harden heat treating in the division takes place at MSP Industries. These two types of heat treating are very similar processes and are therefore grouped together. They typically occur between the forging and machining operations in the process flow. Of MSP Industries' quench temper and neutral harden volume, approximately half of the parts return to MFP Division facility for internal machining while the remainder is machined by outside processors. MSP Industries and MFP Division's staffs are currently exploring an investment in an in-line quench process to eliminate the need for outside heat treatment.

### **6.3.3 Normalizing**

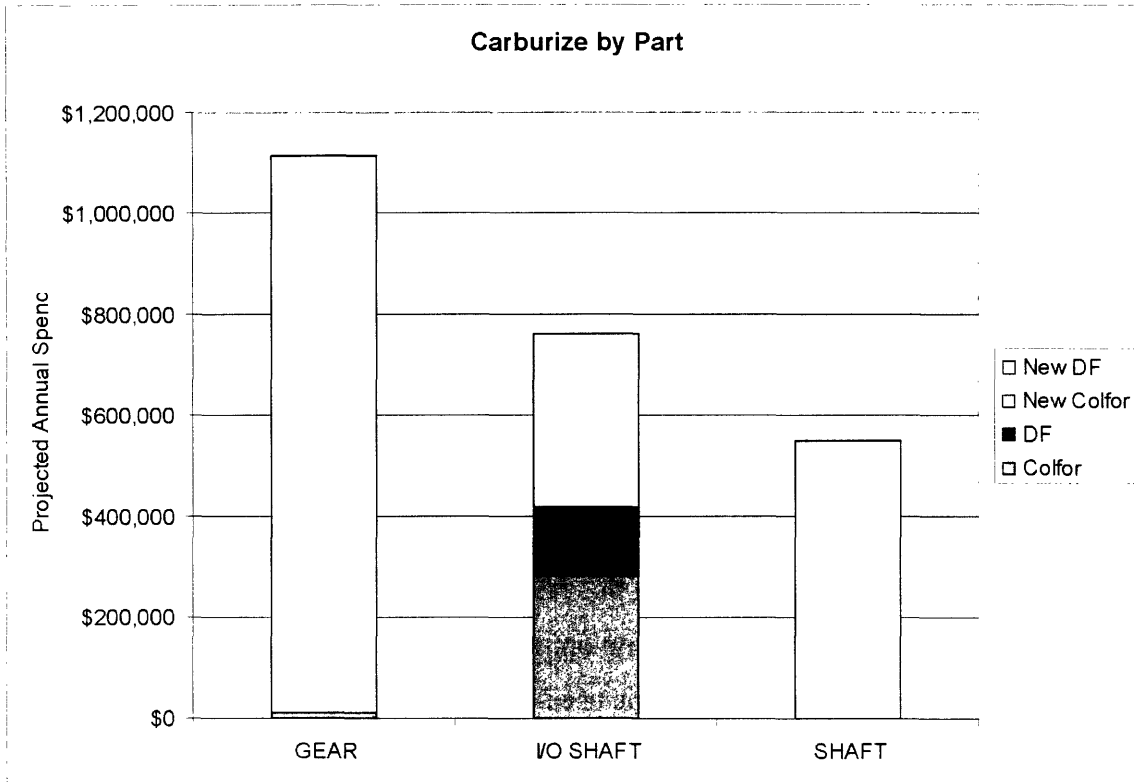
Normalizing is an *in-process forging* heat treating and is a very common process for automotive components. There are over seventy-five parts in the division that are normalized with nearly 85% of those parts forged at Colfor Manufacturing. The author worked with heat treating experts to determine the required investment and operating costs to insource normalizing at Colfor. In spite of the strategic importance of insourcing this process, the initial financial analysis does not look favorable. Currently, the outside cost per pound for normalizing is very inexpensive. Due to the strategic importance, AAM should look at other sourcing options to reduce the capital requirement and improve the financial viability.

### **6.3.4 Spheroidize Annealing**

This process can be classified as both *pre-forging* and *in-process forging*. Nearly 90% of spheroidize annealing volume is a *pre-forging* heat treatment for trunnions. Though *pre-forging* heat treatment is not a target re-sourcing opportunity, the total annual volume is approximately 8 million parts. The sheer volume drove senior management to demand a study for both the *pre-forging* and *in-process forging* volume. A couple different options were proposed. Due to new business requiring spheroidize annealing, the MFP Division staff must now re-evaluate these options.

## **6.4 Carburizing and Vacuum Carburizing**

Carburizing is an *in-process machining* heat treatment. Figure 12 shows the total spending on carburizing within the MFP Division. The graph breaks down the spending by major factors in determining the required furnace capacity. These factors include part type, location where part is forged and timing of the program (e.g. current or future program).



**Figure 12: Carburizing summary**

The majority of the MFP Division's volume is new business at Colfor. This creates a unique opportunity for the division. With the new business ramping up over the next three years, an opportunity exists to invest in carburizing at Colfor and slowly develop the process capability through incremental increases in volume. This factor, coupled with the strategic importance and the potential annual savings, made this the primary focus of this re-sourcing effort.

## 6.5 Alternatives

Having identified the target areas both from a cost/volume and market/strategic perspective, the next step was to identify the alternatives for re-sourcing of carburizing. The author worked with a team composed of metallurgists, business planners and manufacturing engineers. The composition of the team provided expertise in the functional areas required to both generate and evaluate alternatives. This section will describe the options considered by the team, the advantages and disadvantages relative to the strategic and market factors and the financial analysis of each of the options.

### **6.5.1 Sourcing Structures and Alternatives**

Senior management asked the team to identify and evaluate options for the sourcing of heat treating. Hayes, et al. suggests a continuum of structures ranging from vertical integration, where the company has 100% ownership of the process, to an arms-length relationship with suppliers, where the company sources to the supplier through short-term contracts [2005]. One of the intermediate options is “virtual integration” which involves a joint venture between the parties [Hayes et al., 2005]. The team explored the possibility of a joint venture with an outside supplier. The supplier would locate a heat treating facility next to a MFP Division’s plant. The partnership would be formed through shared ownership of facilities and equipment. The major benefits to the relationship are the location of the facility and the ability to share detailed information with the supplier/partner. Though this relationship has many benefits, the team identified three other primary vertical integration options for carburizing. The research conducted by the team on a joint venture will be used for other types of heat treating processes.

### **6.5.2 Factors in Financial Analysis**

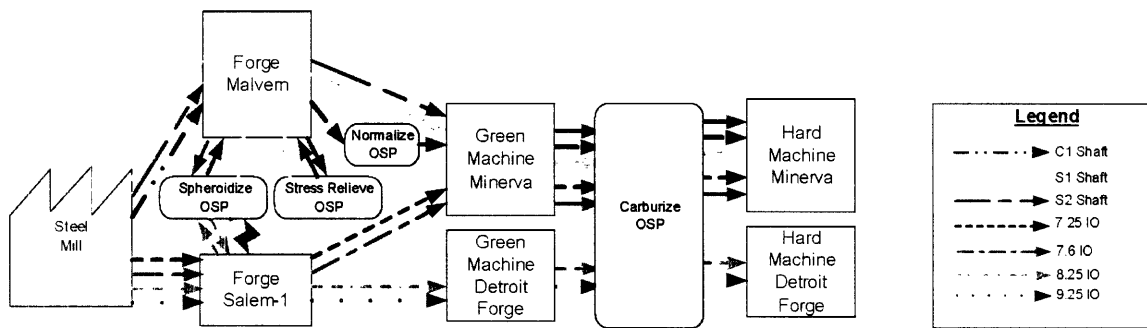
When financially evaluating the options, the following internal and external data were used: outside processing expenses measured by price-per-pound, freight expenses, inventory expenses, direct labor expenses and indirect labor expenses. The analysis does not take into account the transaction costs of dealing with the outside suppliers. The author assumed that insourcing these particular processes would not significantly impact transaction costs. One of the major financial assumptions dealt with labor expenses. In order to account for the benefit of employing laid-off employees, the author used the marginal annual labor costs only when employing laid-off associates.

AAM views a portion of labor expenses as a fixed cost with the remaining portion being variable. The fixed cost is the portion of the annual labor costs that will be paid, due to UAW and IAM agreements, even when an employee is laid off. The marginal annual labor cost is equal to the full labor costs minus the fixed portion. For example, if a laid-off employee receives \$30k per year in wages and benefits and a full time employee earns \$45k per year in wages and benefits, the analysis uses \$15k per year as the effective marginal labor cost. This assumes that certain MFP Division plants will have an infinite pool of laid-off employees from which to use

for new projects for the life of each project. This assumption was approved by AAM Corporate Finance.

### 6.5.3 Description of Current Process Flow

Figure 13 provides a view of the current process flow. This process flow highlights a number of wastes in the system; products travel in and out of MFP Division facilities resulting in excess inventory, waiting, handling and transportation. Exhibit 7 (in Chapter 8 – Exhibits) provides different perspective of the flow of products on a physical map of the Midwest.



**Figure 13: Current carburize part process flow**

The carburizing heat-treatment was the focus of this re-sourcing effort. After extensive brainstorming and analysis, the team identified three primary vertical integration options.

### 6.5.4 Option 1 – Vacuum Carburizing at Detroit Forge and Carburizing at Colfor

This option looked at investing in heat treating equipment in both Detroit Forge and Colfor Manufacturing. The vacuum carburizing furnace at Detroit Forge would heat treat the I.O. shafts. Colfor’s carburizing requirements would be satisfied by relocating a carburizing furnace from the Driveline Division to Colfor’s Salem Plant. The following bullets highlight the advantages, disadvantages, process flow and financial analysis.

- *Advantages of Option 1*
  - Provides control over cost, quality and capacity availability
  - Meets customer preference of control and of end-to-end process flow
  - Invests in new technology (i.e. vacuum carburizing)

- Locates furnaces at each respective plant to better enable flow and eliminate transportation requirements
- *Disadvantages of Option 1*
  - Does not take advantage of divisional economies of scale for carburizing parts
  - Uses older technology for Colfor Manufacturing volume
  - Utilizes a pusher still furnace at Colfor Manufacturing which is difficult to efficiently ramp-up with new marginal volume increases
- *Process Flow for Option 1*

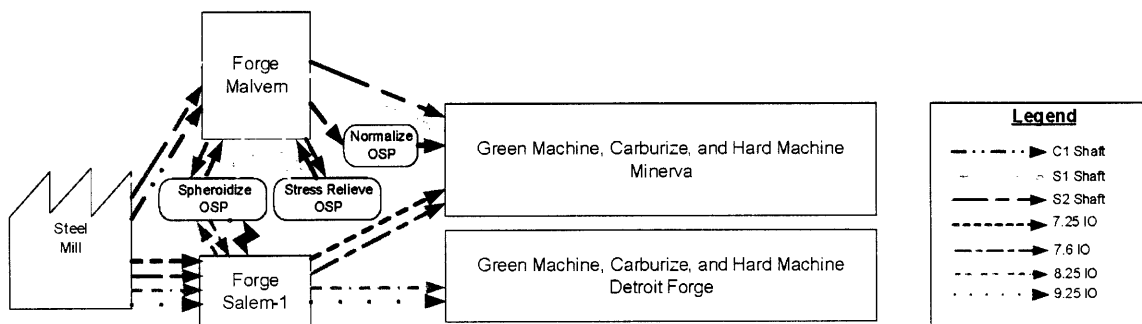


Figure 14: Option 1 carburize part process flow

- *Financial Analysis*

	Detroit Forge	Colfor - Minerva
Capital	\$1M	\$600k
Annual Savings <sup>3</sup>	-\$80k	\$40k

Table 13: Option 1 financial requirements and results

### 6.5.5 Option 2 – Carburizing at Colfor – Salem Plant

This option addresses some of the disadvantages of the option 1 through aggregation of the entire division’s carburizing volume and investing in batch furnaces capable of ramping up volume. This option suggests investing in one carburizing furnace at the Colfor Manufacturing’s Salem Plant, which is currently unoccupied. The following bullets highlight the advantages, disadvantages, process flow and financial analysis.

<sup>3</sup> This annual savings number includes processing, freight and inventory savings. Additional financial analysis was conducted to evaluate the financial benefits of this option. This analysis included calculation of a payback period, a net present value and an internal rate of return. Due to proprietary reasons, these numbers were not disclosed.

- *Advantages of Option 2*
  - Provides control over cost, quality and capacity availability
  - Meets customer preference of control of end-to-end process flow
  - Uses an empty building and idle floor space
  - Takes advantage of divisional economics of scale
- *Disadvantages of Option 2*
  - Creates a "process island" in Salem which is located approximately 45 minutes from the machining line in Colfor's Minerva Plant
  - Does not eliminate wastes in the system; still have excess inventory, waiting, handling and transportation expenses
- *Process Flows of Option 2*

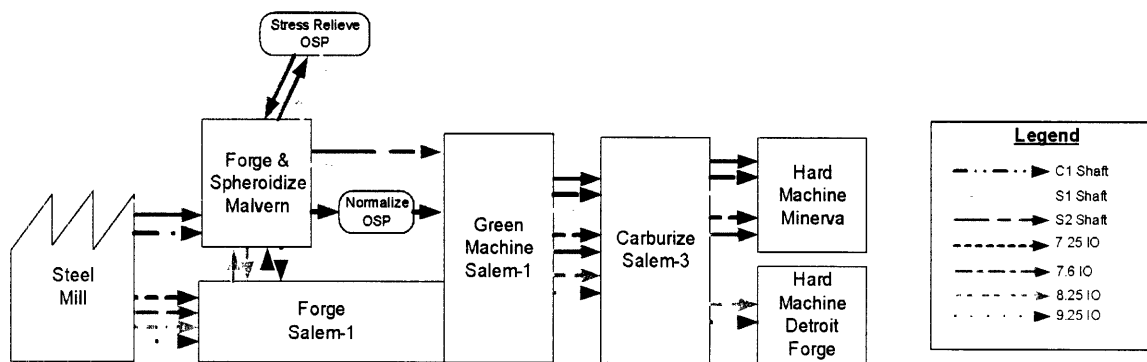


Figure 15: Option 2 carburize part process flow

- *Financials*

	Colfor - Salem
Capital	\$ 1.1M
Annual Savings <sup>+</sup>	\$ 180k

Table 14: Option 2 financial requirements and results

### 6.5.6 Option 3 – Carburizing at Colfor – Minerva Plant

This option addresses some of the disadvantages of both options 1 and 2 through the aggregation of the entire division's carburizing volume, investing in a batch furnace capable of ramping up

<sup>+</sup> This annual savings number includes processing, freight and inventory savings. Additional financial analysis was conducted to evaluate the financial benefits of this option. This analysis included calculation of a payback period, a net present value and an internal rate of return. Due to proprietary reasons, these numbers were not disclosed.

volume and locating the furnace next to the machining line. This option suggests investing in one carburizing furnace in the Colfor Manufacturing's Minerva Plant. In order to accommodate the furnace, the plant needs to be expanded. The following bullets highlight the advantages, disadvantages, process flow and financial analysis.

- *Advantages of Option 3*
  - Provides control over cost, quality and capacity availability
  - Meets customer preference of control of end-to-end process flow
  - Improves the process flow by locating the furnace next to the machining processes
  - Takes advantage of divisional economies of scale
  - Significant reduction in transportation and inventory
- *Disadvantage of Option 3*
  - Requires a large capital investment to expand the building
- *Process Flows for Option 3*

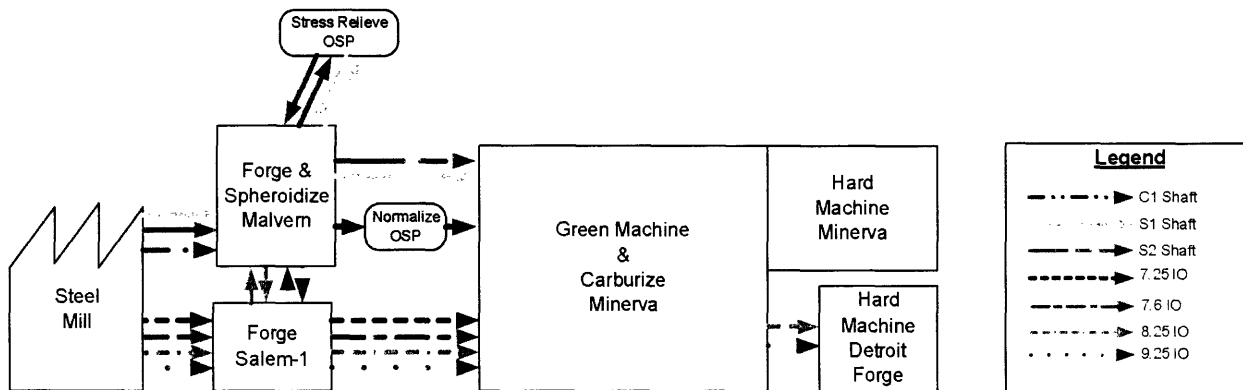


Figure 16: Option 3 carburize part process flow



- *Financials for Option 3*

	Colfor - Minerva
Capital	\$2M
Annual Savings <sup>5</sup>	\$200k

**Table 15: Option 3 financial requirements and results**

## 6.6 Recommendations

The team recommended Option 3 based on a number of reasons. By building onto Colfor’s Minerva Plant, the MFP Division can set up the manufacturing line to better enable process flow. In particular, option 3 does not create a “process island” so it alleviates the need for excess handling, inventory and transportation. Overall, the option addresses the strategic and market considerations while maintaining financial benefits.

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<sup>5</sup> This annual savings number includes processing, freight and inventory savings. Additional financial analysis was conducted to evaluate the financial benefits of this option. This analysis included calculation of a payback period, a net present value and an internal rate of return. Due to proprietary reasons, these numbers were not disclosed.

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## **7. Conclusions and Lessons Learned**

This project was the first effort that took a divisional look at the process flows. The framework to this thesis was the five-step approach for vertical integration decisions. This framework allowed the author to objectively assess all the processes in the division and make recommendations for improvement. The key components within the framework are process flow mapping, market and strategic factors and financial analysis. Together they provide the tools and the structure for AAM's sourcing decisions.

### **7.1 Results and Recommendations**

This thesis provided both the framework and the tool set for making sourcing decisions and used them to make a decision about the sourcing of the heat treating processes. This thesis focused on developing a universal framework to help make sourcing decisions for manufacturing processes in the metal forming industry. The framework and tools resulting from this project can help AAM make sourcing decisions about other manufacturing processes.

By using the framework and tool set, this project resulted in specific recommendations about heat treating processes. Process flow mapping helped to identify the product flows for the entire division and consolidate annual outside processing expenses by manufacturing process. This project also highlighted all the opportunities for re-sourcing manufacturing processes to AAM facilities. In particular, it focused on the analysis used to re-source heat treating processes. This project resulted in a recommendation to invest \$2 million in building and equipment. The results of this work were presented to AAM's Board of Directors and were approved in January 2005.

### **7.2 Key Lessons Learned**

The following are the key lessons learned during this project:

- The benefits of conveying senior management's objectives to associates throughout the organization both clearly and early in the process. This ensures that plants will provide both the support and the resources to meet the objectives. The success of this strategic project was aided by senior level support.

- The importance of aligning corporate strategic goals with each plant's tactical goals. Certain strategic projects do not yield short-term benefits and may be rejected by plants despite the overall significance to the company.
- The advantages of defining a framework early in the project. A clear and concise framework provides a clear roadmap for analysis and for making recommendations.
- The importance of educating senior management about the current state of the supply chain. Process flow maps provide valuable visual tools for senior management to highlight problems and areas for improvement.
- The benefits of process flow mapping for making sourcing decisions. Process flow mapping provides a great tool for highlighting re-sourcing opportunities. It provides the data for financial analysis as well as a visual tool to formulate multiple options to help make financial sense.
- Process flow mapping highlighted non-leveraged buys of outside processing and some purchased materials from the Driveline Division that could be produced by the MFP Division. It highlighted areas for the Purchasing Department to consolidate some sourcing contracts to gain better pricing as well as highlighted forgings purchased from outside supplier that could be produced internally by the MFP Division.
- AAM learned the importance of developing strategic criteria to evaluate and prioritize investments.

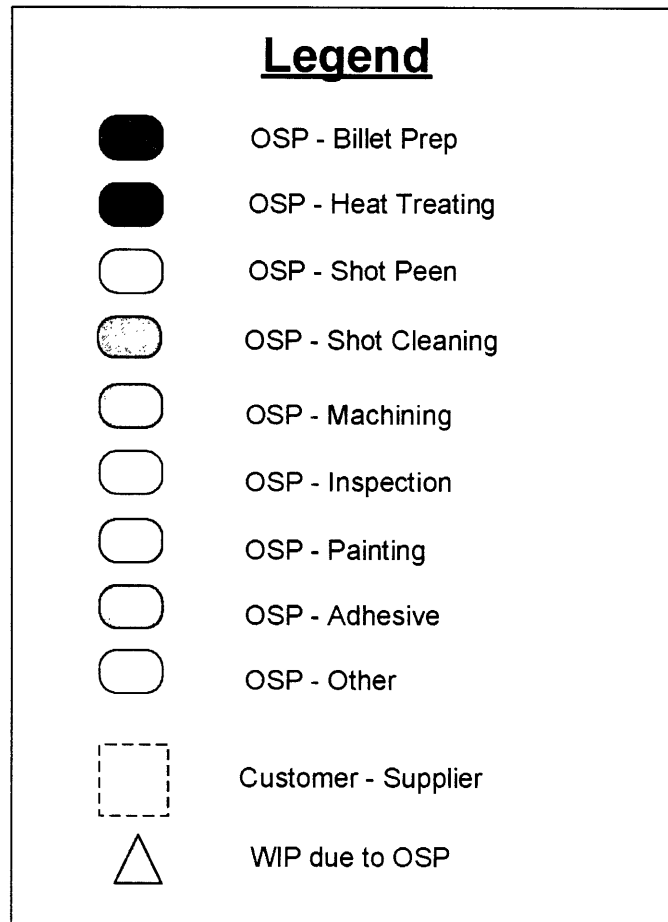
### **7.3 Future Opportunities**

There are a number of areas for American Axle and Manufacturing to explore:

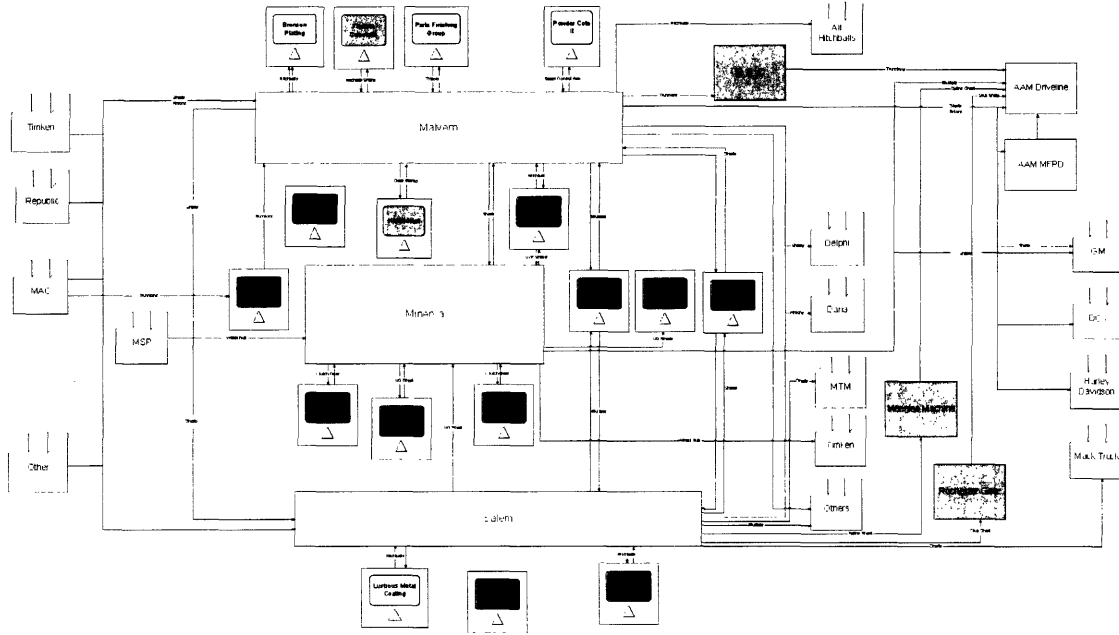
- This project focused on the Metal Formed Products Division. A more thorough analysis would look at all of American Axle and Manufacturing to include the Driveline Division.
- Explore different options for the sourcing of normalizing heat treatment at Colfor. Initial analysis during this project suggests challenging financial implications.
- Further analysis looking into re-sourcing of quench tempering and neutral hardening at MSP Industries. Though MSP Industries is exploring alternatives for portions of the volume, there is still significant volume requiring external heat treatment.
- Process flow mapping revealed opportunities for the re-sourcing of machining activities and the saw cutting of steel bars.

## 8. Exhibits

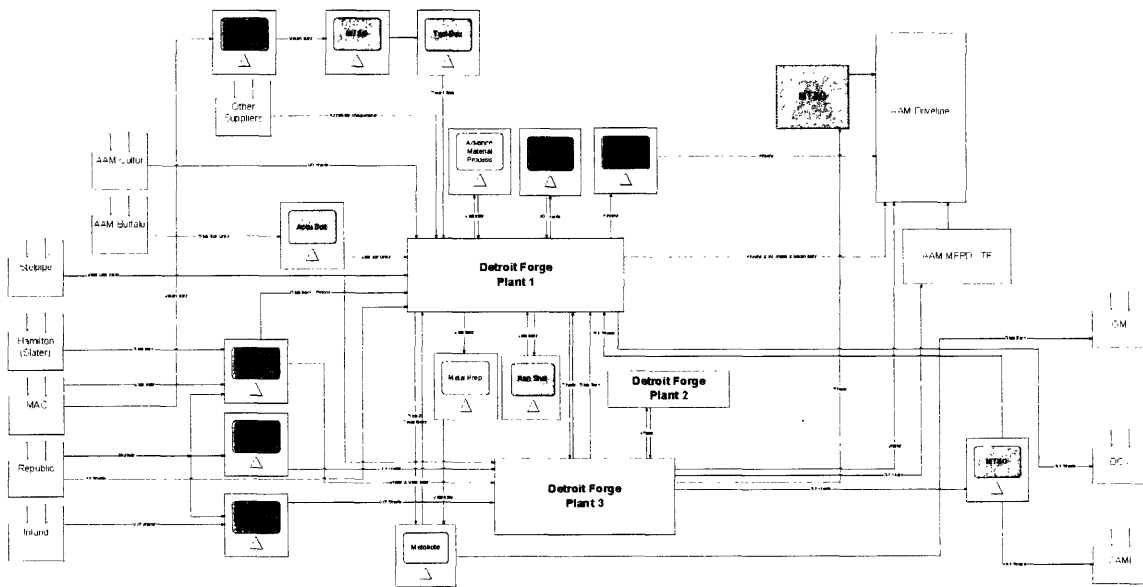
### Exhibit 1: Legend for Process Flow Maps (Exhibits 2 to 6)



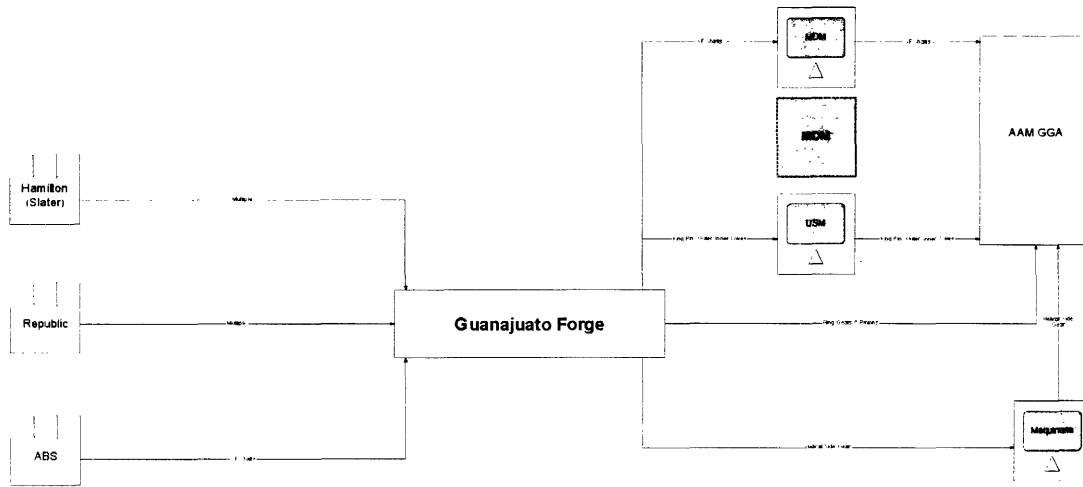
## Exhibit 2: Process Flow Map for Colfor Manufacturing



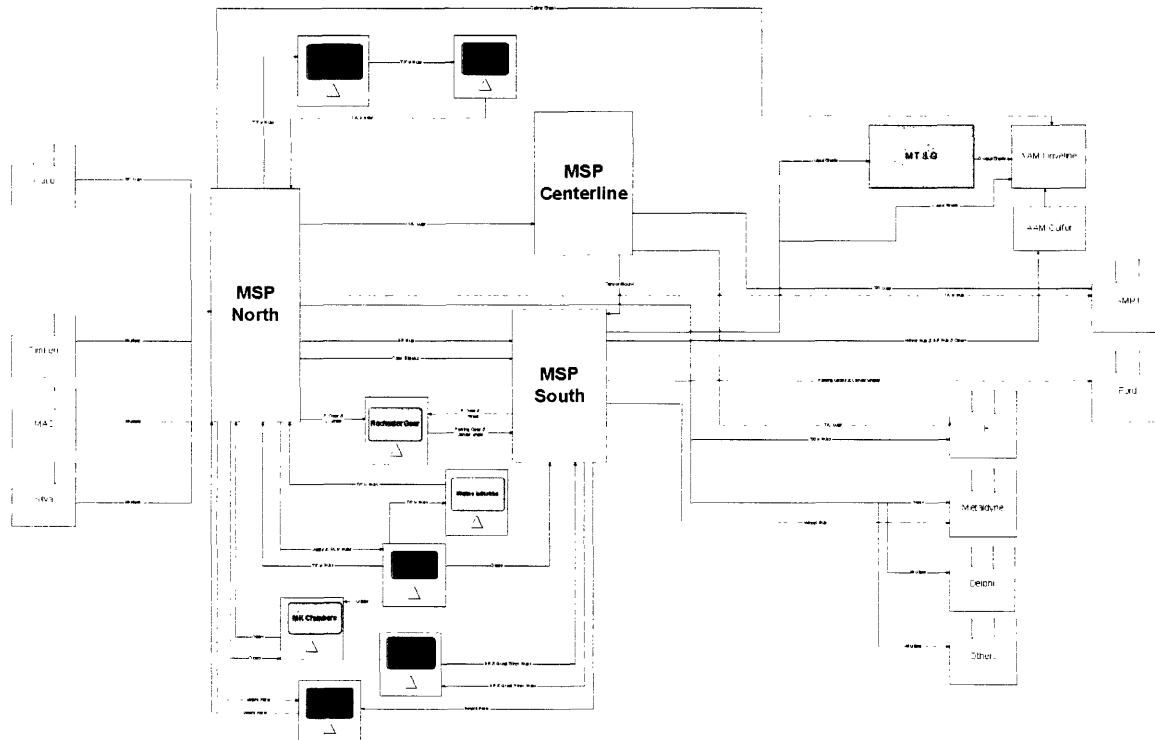
## Exhibit 3: Process Flow Map for Detroit Forge



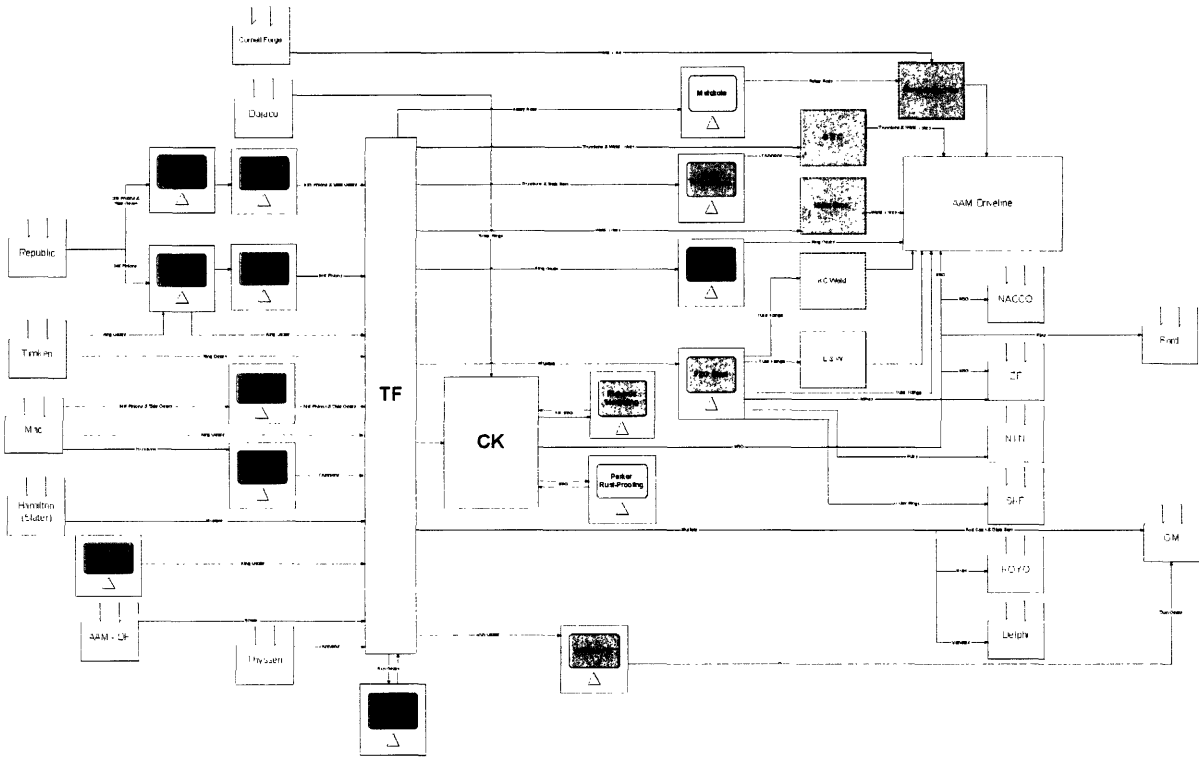
### Exhibit 4: Process Flow Map for Guanajuato Forge



### Exhibit 5: Process Flow Map for MSP Industries

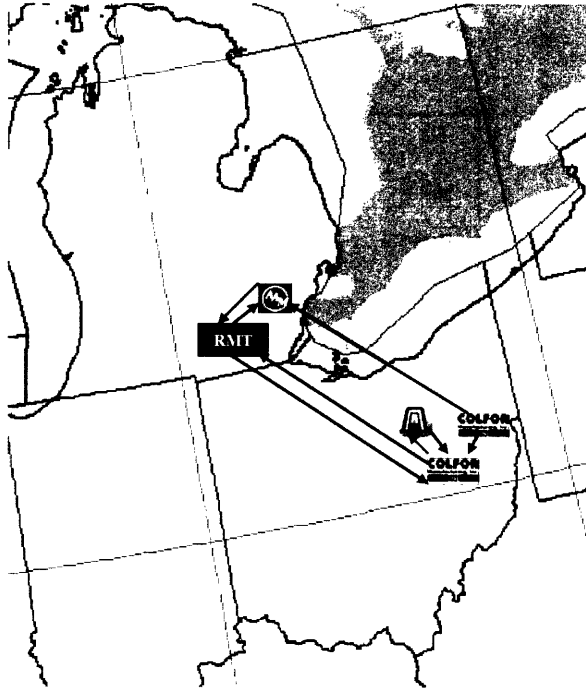








# Exhibit 6: Process Flow Map for Tonawanda Forge and Cheektowaga



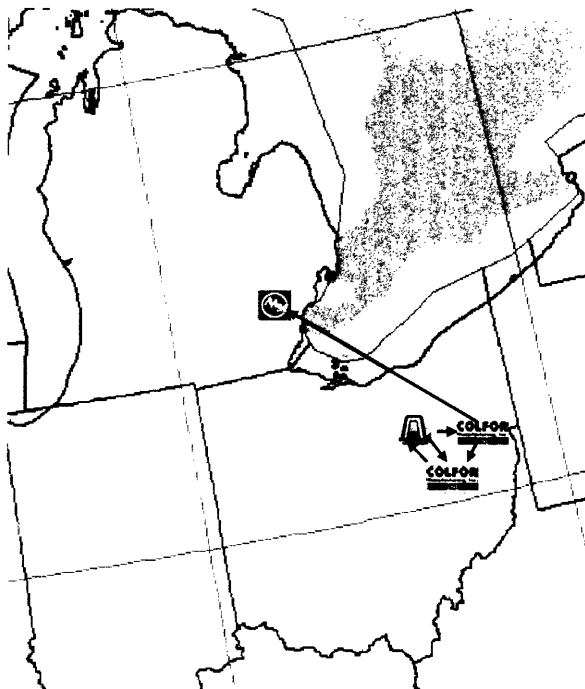








**Exhibit 7: Current process flow for carburize parts**



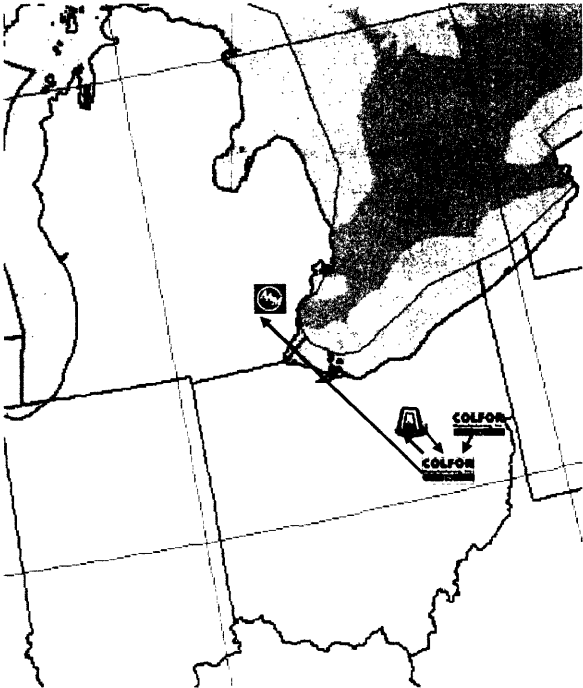
ID	Name	Process
	Colfor - Malvem	Forge
	Colfor - Salem Pt 1	Forge
	Atmosphere Annealing	Spheroidize Stress Relieve Normalize
	RMT Woodworth	Carburize
	Colfor - Minerva	Green Machine Hard Machine
	Detroit Forge	Green Machine Hard Machine






**Exhibit 8: Option 2 for carburize**



ID	Name	Process
	Colfor - Malvem	Forge Spheroidize
	Colfor - Salem Pt 1	Forge Green Machine
	Atmosphere Annealing	Stress Relieve Normalize
	Colfor - Salem Pt 3	Carburize
	Colfor - Minerva	Hard Machine
	Detroit Forge	Hard Machine

**Exhibit 9: Option 3 for carburize**



ID	Name	Process
	Colfor – Malvern	Forge Spheroidize
	Colfor – Salem Plt 1	Forge
	Atmosphere Annealing	Stress Relieve Normalize
	Colfor – Minerva	Green Machine Carburize Hard Machine
	Detroit Forge	Hard Machine

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